Chemical and Sensory profiling of dry and semi-dry South African Chenin blanc wines

by

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Declaration

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Summary

Chenin blanc wine is of economic importance to South Africa and a range of diverse dry and semi-dry wines are locally produced in this genre. Currently, the use of three distinctly different style names, each aimed at providing consumers with information about the flavour of the wines, is encouraged by the South African (SA) wine industry. The styles are fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW). Feedback from retail sectors over the past few years, however, repeatedly suggested that the style names are perceived as confusing by SA consumers. This master study was undertaken to re-evaluate the FF, RRUW and RRW style classification, based on both the volatile fermentation-derived aroma composition and the sensory attributes of a set of wines containing all the styles under investigation.

For the purposes of chemical profiling, a set of 105 commercial Chenin blanc wines, selected to be representative of these three styles and originating from the major SA wine producing areas, were analysed by Gas Chromatography (GC) to quantify fermentation-derived volatile aroma compounds in the wines. ANOVA performed on the chemical data showed that 29 compounds represent significant differences between at least two of the 3 styles (FF, RRUW and RRW). Principal component analysis (PCA) of the volatile compounds showed a large degree differentiation between FF and RRW wine styles, however, RRUW wine styles overlapped with the other two styles. Considering vintage effects, ANOVA indicated no significant differences within FF (vintages 2009 and 2010) and RRW (vintages 2008 and 2009) styles, whereas only 2 esters and 4 terpenes showed significant differences between the three wine producing regions investigated for this purpose, Paarl/Wellington, Breede River and Stellenbosch. Volatile aroma compounds generated for Chenin blanc were included in the Winetech database consisting of the most important cultivars of South Africa. Combining the data for the volatiles for Chardonnay and Sauvignon blanc from this database and the data for Chenin blanc obtained in this study, a PCA indicated a clear separation between Chenin blanc and the other two white cultivars.

Sensory evaluation of the style classification was done by two separate sensory tests. Firstly, a sorting task was performed by wine industry experts to categorise 21 Chenin blanc wines (FF, RRUW and RRW) based on their similarity. The results showed a differentiation between FF and RRW styles, however, RRUW was mostly classified together with FF wines. This indicated a possible continuum between the three styles, as opposed to three distinct different categories, currently suggested by the style names.

The second sensory analysis test, Descriptive Sensory Analysis (DSA), was performed by a trained panel to generate sensory profiles for 42 wines. ANOVA of the flavour attribute intensities between different styles once again showed significant differences between FF and

RRW, with RRUW wines forming a continuum between the FF and RRW styles. These results provide valuable information that could be used by the wine industry for labelling purposes.

Opsomming

Chenin blanc is van ekonomiese belang vir Suid Afrika en ‘n wye reeks droë en semi-droë wyne word plaaslik geproduseer in hierdie kategorie. Tans word die gebruik van drie duidelike verskillende stylbenamings, elkeen daarop gemik om aan die verbruiker inligting te verskaf oor die geur van die wyn, deur die Suid Afrikaanse (SA) wynindustrie aangemoedig. Die style is vars en vrugtig, ryk en ryp ongehout en ryk en ryp gehout. Terugvoer van die handelssektor oor die afgelope aantal jare, het daarop gedui dat die stylbenamings tot verwarring onder SA verbruikers lei. Hierdie meestersstudie is onderneem om die stylklassifikasie, vars en vrugtig, ryk en ryp ongehout en ryk en ryp gehout, te her-evalueer op grond van die vlugtige aroma komponente wat tydens die fermentasie proses gevorm word, asook die sensoriese eienskappe van ‘n verteenwoordigende stel wyne van elk van die style wat ondersoek is.

Vir die doel van die chemiese profilering, is ‘n stel van 105 kommersiële wyne, wat geselekteer is om verteenwoordigend te wees van die drie style ondersoek en ook afkomstig is van die vernaamste SA wynproduserende streke, gebruik. Die wyne is met behulp van gas chromatografie ontleed om die vlugtige komponente wat van die fermentasie proses afkomstig is, te kwantifiseer. Die analise van variansie, het getoon dat 29 komponente statisties beduidend verskil het tussen die drie style. Hoofkomponent analise van die vlugtige komponente, het getoon dat die vars en vrugtige wyne en ryk en ryp gehoute wyne, duidelik onderskeibaar was van mekaar op grond van die vlugtige data, maar die ryk en ryp ongehoute wyne het met die ander twee style oorvleuel. In terme van oesjaar effekte, was daar geen beduidende verskille in die aroma profiele van die vars en vrugtige styl (oesjare 2009 en 2010) en ryk en ryp ongehoute styl (oesjare 2008 en 2009) nie, terwyl die konsentrasie van slegs twee esters en 4 terpene statisties beduidend verskil het tussen die wynproduserende streke Paarl/Wellington, Breederivier en Stellenbosch. Resultate van die gekwantifiseerde vlugtige komponente is in die databasis van Winetech gevoeg, waar die konsentrasies van soortgelyke komponente van die vernaamste SA wynkultivars reeds vervat is. Hoofkomponent analises van die gekombineerde resultate vir Chenin blanc, Chardonnay en Sauvignon blanc wyne, het getoon dat daar ‘n duidelike verkil tussen Chenin blanc en die ander twee wit wynkultivars was.

Die sensoriese evaluerings is uitgevoer deur van twee verskillende metodes gebruik te maak. Eerstens is 21 wyne (met al drie style verteenwoordig) deur wynindustrie eksperts gesorteer op grond van die waargenome eendersheid van die onderskeie wyne en die resultate is grafies geprojekteer. Die resultate het getoon dat daar ‘n duidelike verskil waargeneem is deur die assessors tussen die vars en vrugtige styl en ryk en ryp gehoute styl. Die ryk en ryp ongehoute wyne het in die analises meer met die vars en vrugtige style geassosieer, as die ryk en ryp gehoute wyne.

Die tweede sensoriese metode is uitgevoer deur sensoriese paneel wat vir die doel van hierdie studie opgelei is om die geur eienskappe van 42 wyne (al drie style verteenwoordig) te

profileer. Analise van statistiese beduidende verskille tussen die voorkoms van die geurkomponente en hul intensiteite vir elke styl, het weereens aangedui dat daar ‘n kontinuum bestaan tussen die style. Hierdie resultate kan van waarde vir die wynindustrie wees in besluite rakende etikettering.

This thesis is dedicated to my loving husband, father, mother and brother who supported and encouraged me every step of the way.

Biographical sketch

Lindi van Antwerpen was born in Calvinia, Northern Cape, South African on 16 January 1987. She matriculated at Calvinia High School in 2005. Lindi obtained a BScAgric-degree in Food Science at the University of Stellenbosch in 2009. In 2010 Lindi enrolled for an MSc in Wine Biotechnology at the Institute for Wine Biotechnology, Stellenbosch University.

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Preface

This thesis is presented as a compilation of 5 chapters. Each chapter is introduced separately and is written according to the style of the South African Journal of Enology and Viticulture to which a combination of Chapter 3 and 4 is under preparation for submission.

Chapter 1	**Introduction, problem statement and project aims**
Chapter 2	**Literature review**
Part 1	Introduction to Chenin blanc with focus on global distribution, international perceptions of wine quality and style versatility
Part 2	Chemical profiling of wine with specific focus on Chenin blanc
Part 3	Sensory evaluation of wine
Chapter 3	**Research results** Characterisation of the volatile aroma composition of South African dry and semi-dry Chenin blanc wine styles
Chapter 4	**Research results** Sensory profiling of South African Chenin blanc wine styles
Chapter 5	**General conclusion**

Contents

Chapter 1. INTRODUCTION, PROBLEM STATEMENT AND PROJECT AIMS **1**

1.1 General introduction **2**
1.2 Project aims, outcomes and experimental design **4**
1.2.1 Characterisation of the volatile aroma composition of South African dry and semi-dry Chenin blanc wine styles (Chapter 3) 4
1.2.2 Sensory profiling of South African Chenin blanc styles by using a sorting task and Descriptive Sensory Analysis (Chapter 4) 4
1.2.3 Specific outcomes of this study 5
1.2.4 Experimental design 6
1.3 References 6

Chapter 2. LITERATURE REVIEW **8**

2.1 Part 1: Intoduction to Chenin blanc with focus on global distribution, international perceptions of wine quality and style versatility **10**
2.1.1 Introduction 10
2.1.2 Loire Valley, France 10
2.1.3 California, USA and Argentina 12
2.1.4 Australia and New Zealand 12
2.1.5 South Africa 13
2.1.5.1 South African statistics of Chenin blanc vineyards and wine 13
2.1.5.2 International perceptions of South African Chenin blanc wine quality 17
2.1.5.3 Versatility of South African Chenin blanc wine styles 18
2.1.6 Conclusions 20
2.2 Part 2: Chemical profiling of wine with specific focus on Chenin blanc **20**
2.2.1 Introduction 20
2.2.2 Fermentation-derived compounds 22
2.2.3 Terpenes and related compounds 23
2.2.4 Organic acids 23
2.2.5 Other compounds that could make a significant contribution towards Chenin blanc wine flavour 24
2.2.6 Quantification of volatile compounds 24
2.2.7 Conclusion 25
2.3 Part 3: Sensory evaluation of wine **26**
2.3.1 Introduction 26
2.3.2 Descriptive Sensory Analysis (DSA) 27
2.3.2.1 Panel selection and generation of product descriptors 28
2.3.2.2 Panel training 28
2.3.2.3 Product testing 29
2.3.2.4 Data analysis 29
2.3.3 Rapid low cost sensory analysis 29
2.3.3.1 The sorting task 30
2.3.3.2 Analysis of data obtained with sorting tasks 31
2.3.4 Correlation between sensory and chemical data 31

2.3.5 Conclusion 32
2.3.6 References 32

Chapter 3. Characterisation of the volatile aroma composition of South African dry and semi-dry Chenin blanc wine styles **39**

3.1 Introduction **41**
3.2 Materials and Methods **44**
3.2.1 Wines 44
3.2.2 Chemicals, standards and wine simulant 44
3.2.3 Analysis of major volatile aroma compounds 45
3.2.4 Analysis of terpenes and related compounds 45
3.2.5 Quantification of basic wine parameters 46
3.2.6 Data analysis 46
3.3 Results and Discussion **48**
3.3.1 Chemical profiles of different Chenin blanc styles 48
3.3.2 Differences between Chenin blanc wine producing areas 54
3.3.3 Comparison of volatile composition between white wine cultivars 55
3.4 Conclusions **60**
3.5 References 61

Chapter 4. Sensory profiling of South African Chenin blanc styles **65**

4.1 Introduction **66**
4.2 Materials and Methods **68**
4.2.1 Sorting task performed by untrained wine experts 68
4.2.1.1 Wines 68
4.2.1.2 Sorting task: design and procedures 69
4.2.1.3 Data analysis 69
4.2.2 Descriptive analysis by the trained panel 70
4.2.2.1 Wines 70
4.2.2.2 Descriptive Sensory Analysis: designs and procedures 70
4.2.2.3 Data analysis 71
4.3 Results and Discussion **73**
4.3.1 Sorting results 73
4.3.2 Descriptive Sensory Analysis (DSA) results 77
4.4 Conclusions **81**
4.5 References **81**

Chapter 5. GENERAL CONCLUSIONS **84**

5.1 Conclusions **58**

Addendum A: Questionnaire used for evaluation of individual wines **87**

Chapter 1

Introduction, problem statement and project aims

INTRODUCTION, PROBLEM STATEMENT AND PROJECT AIMS

1.1 General introduction

Chenin blanc is the most planted variety in South Africa and covers 18.2% of the total grape plantings in the country. This cultivar is of great economic importance to South Africa with Chenin blanc wine export figures for 2011 at 46 584 507 litres (SAWIS, 2012). These figures represent more than a 13% increase since 2009 (SAWIS, 2012). In the past, Chenin blanc has been referred to as a "workhorse variety" in South Africa and the grapes were mainly used for the production of brandy and bulk wine blends. A renewed interest in Chenin blanc's potential as wine of quality started in the 1990's and since then, the momentum for production of top quality wines has been driven by the Chenin Blanc Association (CBA) (CBA, nd). The Chenin blanc Challenge, an annual local wine competition, was instituted in 1996 to raise awareness of Chenin blanc wine quality. The results of this competition showed that the quality and standards of Chenin blanc have been rising consistently (Winemag, 2009; 2010; 2011; 2012). Recently, two South African Chenin blanc wines received gold medals at the International Wine Challenge (Eedes, 2011).

Chenin blanc is an extremely versatile grape variety and various wine styles are produced from across the different winemaking regions of South Africa. Three dry and semi-dry wine styles are currently recognised: fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW) (CBA, nd). FF wines are associated with younger vintages available in the market, as these wines do not normally undergo an ageing period. These wines typically have an ageing potential of 12 – 18 months. RRUW wines that do not receive wood contact are usually kept on the fine lees for periods between three to six months, during which time flavour complexity and a fuller mouth-feel develop in the wine. RRW wines are generally associated with older vintages due to a maturation period in oak. The rich and ripe styles have an ageing potential between two and even up to ten years (O'Kennedy, 2009). These style descriptions are also shown on the packaging labels and the CBA encourages producers to use this style classification in local marketing of Chenin blanc wines.

A critical review of the available scientific literature on Chenin blanc wine showed that, to date, very limited research has been done on profiling of the chemical and sensory properties of this cultivar. Most of the research done on chemical aspects, dates back more than three decades, as reviewed by Marais (2003), while sensory data can mostly only be retrieved from the popular wine press. It has been suggested that different viticultural practices applied to cultivation of the Chenin blanc grape and vinification techniques used during winemaking, can have a major impact on the final quality of Chenin blanc wine (Loubser, 2008). However, very few scientific studies have been done to date to investigate these claims and they remain largely speculative.

The current style classification, however, reportedly leads to confusion amongst South African consumers, since they do not know what to expect from the flavour of Chenin blanc wine, even when the style or flavour description is indicated on the packaging label (Brower, 2009). There is also the concern that there are no defined guidelines for the definition of each style classification.

Based on this review of the literature on Chenin blanc, there is clearly a need to do a comprehensive survey of the chemical and sensory properties of South African Chenin blanc wines to investigate if there are significant differences between the different wine styles. This thesis reports on the first round of profiling of a large set of commercial Chenin blanc wines and these tasks form the major objectives in the research design of this master thesis.

In addition, the study investigated if the chemical composition of the wine styles remained constant over vintages, in order to address the question if the profiles associated with the different styles were stable over consecutive years. The results of this finding will have an influence on attempts to set up criteria for style classification. This task could only be done for the FF and RRW styles in this research project, since the RRUW category is a relatively small group and the limited number of wines precluded an investigation of this nature. It was also of interest to investigate the possibility of regional influences on the chemical profiles of Chenin blanc wines. Thus, the differences between wines originating from important Chenin blanc wine production regions, including Stellenbosch, Paarl, Wellington and Breede River were investigated. This will identify if wines from certain regions have a regional character that can be distinguished from each other. This task was only applied to the FF wines, since changes in the volatile content due to ageing in the RRUW and RRW styles may overshadow the influence of wine producing area.

It was of interest to evaluate two separate sensory methods for style classification, namely the sorting task (Lelièvre *et al*., 2008) and the descriptive sensory analysis (DSA) technique (Lawless and Heymann, 2010). The objectives with the sorting tasks were firstly to evaluate how the different Chenin blanc style categories were perceived by wine industry experts, and secondly, to test if wine experts could correctly identify the styles of a each wine in a set of Chenin blanc wines presented to them. The second method involves the generation of sensory data by a trained panel using the DSA technique. The specific aim for this study was to investigate if there were significant differences in the sensory attributes of the styles under question. It was also important to investigate how well the results obtained with the sorting tasks correlated with those obtained with DSA. The former technique is a much faster and lower cost sensory evaluation method in comparison to DSA, and could play an important role, if shown to deliver reliable data, in future South African wine sensory studies.

1.2 Project aims, outcomes and experimental design

The two main objectives of this study and the specific tasks associated with each, are listed below.

1.2.1 Characterisation of the volatile aroma composition of South African dry and semi-dry Chenin blanc wine styles (Chapter 3)

a) identification of a set of Chenin blanc wines representative of style, vintage and area
b) quantification of volatile compounds and basic wine parameters to investigate significant differences between:
    i) FF, RRUW and RRW styles
    ii) different vintages of FF and RRW wines
    iii) different wine production areas
    iii) Chenin blanc and other SA white wine cultivars

1.2.2 Sensory profiling of South African Chenin blanc styles by using a sorting task and Descriptive Sensory Analysis (Chapter 4)

a) determine if wine industry experts could identify the three styles, FF, RRUW and RRW of Chenin blanc with the sorting technique
b) determine if there are significant sensory differences between FF, RRUW, RRW styles, based on the aroma and taste attributes evaluated by DSA and a trained panel

It was not an objective of this study to find correlations between chemical and sensory data, for the purpose of interpreting which chemical compound is associated with which sensory attribute. It is crucial to take into consideration that some volatile compounds can mask the sensory perceptions of other compounds, as well as act synergistically to produce new perceived aromas in wine (Noble and Ebeler, 2002). The task to do this type of investigation is complex and requires flavour impact studies, amongst other advances analytical tests.

1.2.3 Specific outcomes of this study

Data pertaining to the volatile composition of a large number of commercial Chenin blanc wines will be determined and used to expand the existing Winetech database on South African wines, that was recently established (Louw, 2009). The database currently contains the aroma components of six South African cultivars, including Cabernet Sauvignon, Shiraz, Merlot, Pinotage, Chardonnay and Sauvignon blanc. The data are considered as a chemical fingerprint of the wines tested and can be used for authentication and benchmarking purposes (Marais, 2007).

Publications under preparation

Dissemination of the information to the popular South African wine press will be done in a series of three publications in Wineland, currently under preparation to be submitted. One full-length scientific publication in a peer-reviewed journal is also currently under preparation, for submission to the South African Journal of Enology and Viticulture.

Conference presentations

(1) Van Niekerk, L., A. Tredoux, T. Næs, N., Muller & H. Nieuwoudt. **2010**. South African Chenin blanc wines: New insights on the chemistry, sensory profiles and consumer preference. 32nd SASEV Congress, Lord Charles Hotel, Somerset West. POSTER (18-19 November 2010)

(2) Van Antwerpen, L., A. Tredoux, T. Næs, N., Muller & H. Nieuwoudt. **2011**. Chemical and sensory profiling of dry Chenin blanc wine styles. 33nd SASEV Congress, Protea Hotel, Technopark, Stellenbosch. PRESENTATION. (10 – 11 November 2011) South African Chenin blanc wines

(3) Van Antwerpen, L., A. Tredoux, T. Næs, N., Muller & H. Nieuwoudt. **2011**. Chemical and sensory profiling of dry Chenin blanc wine styles. Chenin Blanc Association Conference. Joostenberg, Stellenbosch. (14 November 2011)

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1.2.4 Experimental design

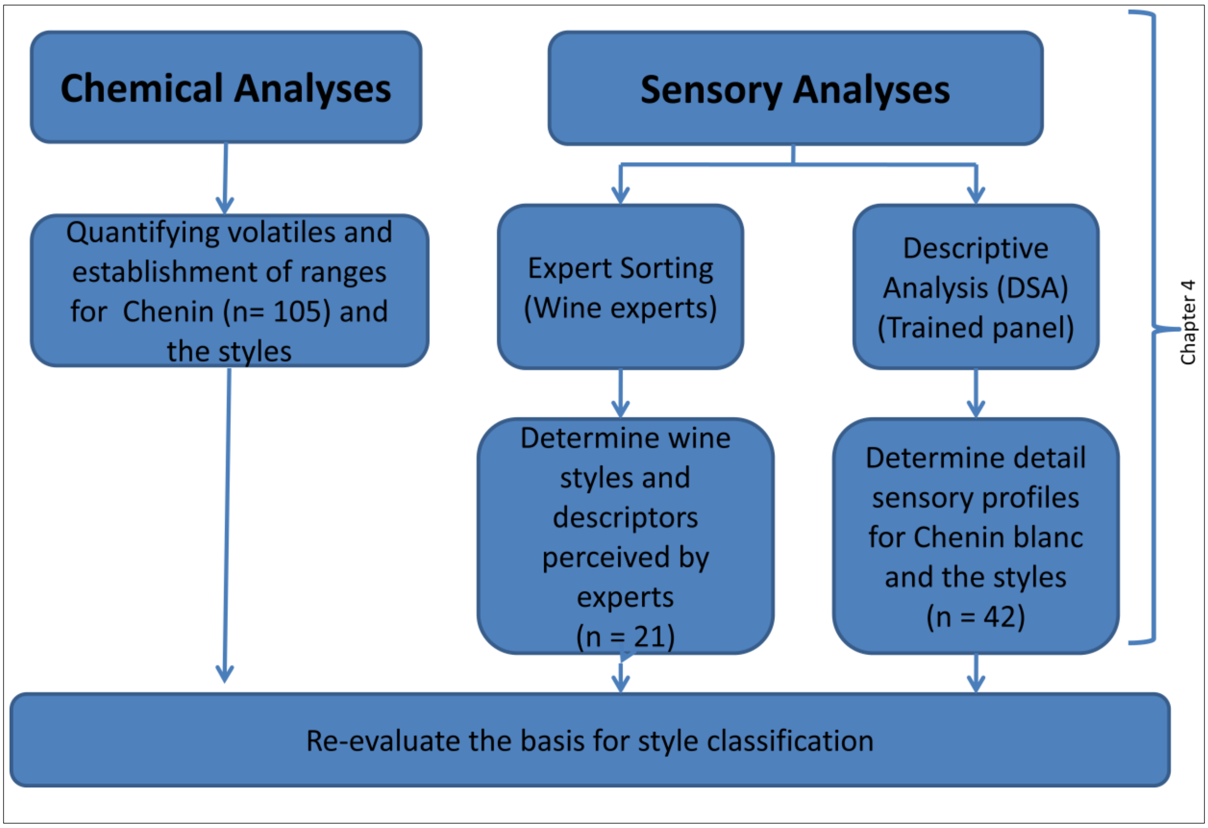

Figure 1.1 Summary of the experimental design and main objectives of the project.

Chapter 3 focuses on the results obtained with the volatile compound profiling of the wines, whereas Chapter 4 focuses on results obtained with sensory profiling.

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Chapter 2

Literature review

LITERATURE REVIEW

The Merriam-Webster's Collegiate Dictionary (2005) defines a profile as "a set of data often in graphic form, portraying the significant features of something". Based on the important role that chemical and sensory attributes play in determining a wine's characteristics, wine profiling can therefore be described as the processes by which data regarding the chemical and sensory characteristics are obtained, followed by extraction of the significant information from the data. These different types of characteristics can also be correlated to give a more comprehensive "fingerprint" or understanding of a wine.

Chenin blanc is the most planted variety in South Africa and covers 18.2% of the total grape plantings (SAWIS, 2012). This cultivar is of great economic importance to South Africa with rising exports that are currently at 46 584 507 litres (SAWIS, 2012). Chenin blanc was thought of as a "workhorse variety" in South Africa and was mainly used for the production of brandy and bulk wine blends (CBA, nd). However, South Africa has made an effort to improve the quality of Chenin blanc wines, and the country is emerging to be recognised internationally, as a producer of world class Chenin blanc wine (Fridjhon, 2006). A review of the published scientific research on Chenin blanc, however, showed that very little information is available and the need to establish chemical and sensory profiles for Chenin blanc wines is clear.

This literature review consists of three parts. The first part is a brief and general discussion of Chenin blanc wine. Reference is made to the Chenin blanc grape, the cultivar's history, global distribution, production statistics and the versatility of South African Chenin blanc wine styles. In the second part, the profiling of chemical characteristics of wine and the benefits and potential applications of the data, are discussed. The focus is on volatile compounds and the analytical methods used for their quantification, while some other classes of chemical compounds that are important for the sensory profiles of Chenin blanc, are also mentioned. In the third and final part, the focus is on sensory profiling of wine. Different methods and data interpretation are discussed.

2.1 Part 1: Introduction to Chenin blanc with focus on global distribution, international perceptions of wine quality and style versatility

2.1.1 Introduction

Countries that cultivate Chenin blanc grapes, together with the total hectares planted, are shown in Figure 2.1 and include South Africa, France, California (USA), Argentina, Australia, Mexico, New Zealand and Israel (Clarke, 2007). Of these countries, South Africa and France have the largest areas planted with this grape and they are also considered important role players in developing the potential of Chenin blanc wines (Clarke, 2007). In the past few decades, South Africa has made an effort to improve the quality of Chenin blanc wines, and the country is emerging to be recognised internationally, as a producer of world class Chenin blanc wine (Fridjhon, 2006). In the next section, the most important Chenin blanc producing countries are discussed with the emphasis on South African Chenin blanc.

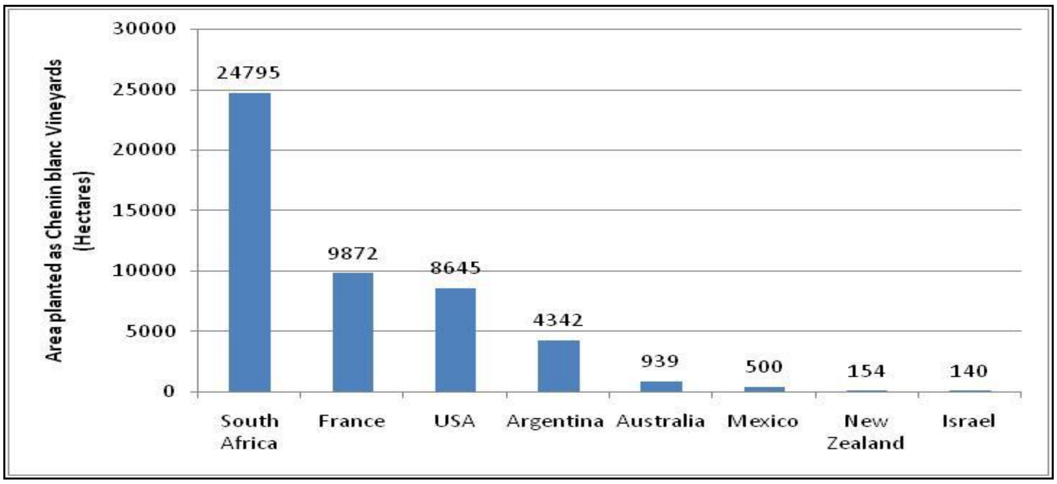

Figure 2.1 Comparison of areas planted under Chenin blanc vineyards in different countries in 2007 (Clarke, 2007).

2.1.2 Loire Valley, France

The Loire Valley, France, is associated with the world's finest quality Chenin blanc wine. The earliest historical record, that mentions the Chenin blanc grape variety, reportedly dates back as early as the 9th century and locates the Anjou region, France, as its origin (CBA, nd). The variety, first known as Chenere, was officially named Chenin blanc in the 15th century (Loubser, 2008). The Chenin blanc variety is also known in France as Pineau de la Loire and is occasionally referred to as Pineau d'Anjou (Wilson, 1998).

The Loire Valley (Figure 2.2) covers a great area of land and follows the Loire river from the Atlantic Ocean near Nantes, all the way east and south almost to the Rhône. This area has a large variation in climate and soil types. The Loire splits into three separate sections with four distinctive viticultural appellations. The western Loire, near the Atlantic coast, is the home of the Muscadet region. Wines from this area have a "yeasty-yet-fresh" quality. Anjou is situated centrally, next to Muscadet. East of Anjou is Vouvray where Chenin blanc wines are predominately produced. Sancerre and Pouilly-Funé is situated in the upper Loire (Greenberg, 2011).

The French law requires the use of an appellation system. The *Appelation of Origin (A.O.C.)* should appear on the wine label if the requirements of the appellation are met. The appellation system is based on region, village and near villages (Greenberg, 2011). This implies that Chenin blanc wine will be labelled for example as Anjou, Savennières, Jasnières or Vouvray amongst others (Fraley, 2012). A few examples of Chenin blanc wines from the Loire Valley are *"Champalou Vouvray, Loire Valley, France", "Domaine des Aubuisieres Vouvray Cuvee de Silex",* and *"Baumard Savennieres Trie Speciale".*

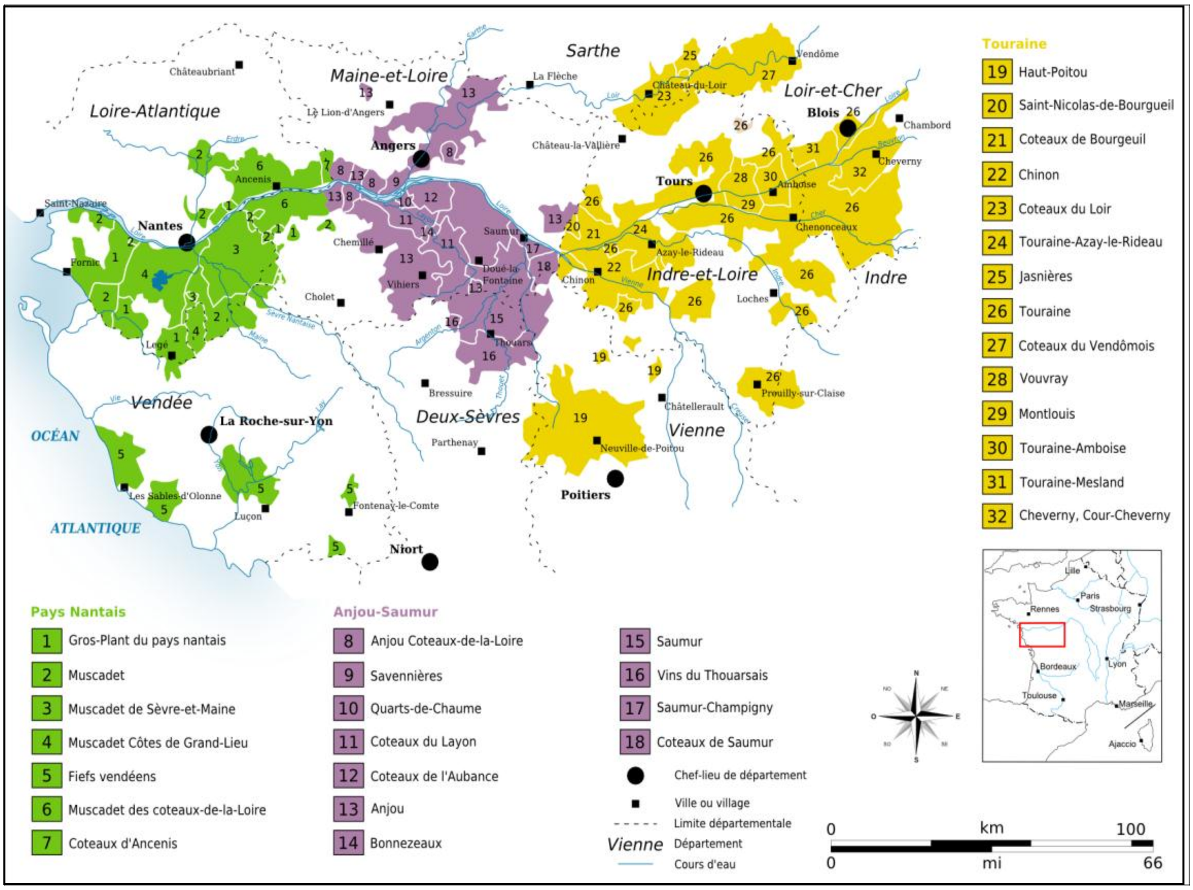

Figure 2.2 The Loire Valley in France (e-notes, 2012).

2.1.3 California, USA and Argentina

In California, the total area of Chenin blanc vineyard plantings increased from 5 060 hectares in 1976 (Massee, 1974), to 13 220 hectares in 1993 (Beazley, 1993). Since then, the plantings decreased considerably to 8 645 hectares based on most recent available sources shown in Figure 2.1 (Clarke, 2007). Chenin blanc produces fresh and flowery wines and is has also been called White Pinot in California. California's Chenin blanc vineyards are more concentrated in the hot Central Valley (Clarke, 2007), where it is cultivated to produce larger amounts per hectare than normally associated with excellent quality wines (Boehmer, 2009). Chenin blanc is mostly produced as early available, semi-dry, fruity wines that satisfy the local market (Beazley, 1993). Some good quality wines with stylish fruity flavours are also produced, particularly in the Clarksburg region in the Sacramento Delta (Clarke, 2007).

Limited information is available regarding Chenin blanc wine of Argentina. This cultivar is mostly blended with other wines to increase acidity. The grapes are used to produce different styles of wine including dry, fortified, dessert and sparkling wines (Karlin, 2011).

2.1.4 Australia and New Zealand

Plantings of Chenin blanc have declined in Australia and were at 939 hectares in 2007 (Figure 2.1). Wines produced from Chenin blanc, are characterised by soft fruit salad flavours. The vines are widely distributed throughout the country although better quality wines have been produced in the Western area including Swan Valley and Margaret River (Clarke, 2007).

New Zealand has a very suitable climate for Chenin blanc, but only 154 hectares are cultivated with this cultivar (Figure 2.1). New Zealand Chenin blanc vineyards are situated mostly on the North Island. The cultivar is mainly used in inexpensive blends due to the high acidity of the grapes. Chenin blanc can also produce excellent wines with balance and fruity flavours that range from greengage and angelica, honey and lemon acidity. Even though high quality Chenin blanc wine is produced, it is sold at a less expensive price than Sauvignon blanc or Chardonnay wine. For this reason Chenin blanc remains a minor variety in New Zealand (Clarke, 2007).

2.1.5 South Africa

South Africa has the largest area planted with Chenin blanc vineyards compared to other wine producing countries (Figure 2.1). Chenin blanc was introduced to South Africa in 1652 with the arrival of Jan van Riebeeck in the Cape (Clarke, 2007). Three varieties were documented and included Groendruif (Semillon), Fransdruif and Steen. The Steen variety was reagarded for many years to be unique to the Cape, until Professor C.J. Orffer, head of the department of viticulture at the University of Stellenbosch, established in 1963 that this variety was in fact Chenin blanc (CBA, nd).

South African Chenin blanc wine quality is often compared to that of their French counterpart (James, 2011). French wines do not display the variety of the wine on the label, but are rather marketed under the appellation (*A.O.C.*) where the wines are produced (Greenberg, 2011). However, South Africa market Chenin blanc wines extensively under the Chenin blanc varietal label, making it the only country that focus directly on the marketing of the variety (Lloyd, 2010).

2.1.5.1 South African statistics of Chenin blanc vineyards and wine

Chenin blanc is of great economic importance to South Africa. The latest statistics provided by the South African Wine Industry Information and Systems (SAWIS, 2012), shows that Chenin blanc is the most planted grape variety in South Africa (18.2%), followed by Cabernet Sauvignon (12.0%) and Colombar (11.8%) as shown in Table 2.1. Internally, Chenin blanc plantings decreased over the past 10 years, as shown in Figure 2.3, however, the variety still remained to be the largest planted variety amongst all white cultivars (SAWIS 2011). The most recent statistics (SAWIS, 2012) indicate that Chenin blanc plantings are currently at 18 326 hectares (Table 2.1).

Recent statistics (SAWIS, 2012) showed that Chenin blanc wine volumes that were sold in 750 mL glass containers for 2011, amounted to 3 091 773 litres in comparison with Sauvignon blanc (10 464 299 Litres) and Chardonnay (3 264 462 litres). Despite a downward trend in overall 2011 exports of SA wine, the total volumes of Chenin blanc wine exports are increasing positively, as evident from statistics of 2009 (41 087 949 litres), 2010 (46 255 791 litres) and 2011 (46 584 507 litres). Figures for 2011 included bulk Chenin blanc wine exports (30 364 243 litres) and packaged exports (16 220 264 litres). Countries that import significant volumes of SA Chenin blanc wine include the United Kingdom, The Netherlands, Sweden, Denmark and also recently China (SAWIS, 2012).

Wine growing regions in South Africa include the Orange River, Oliflants River, Malmesbury, Little Karoo, Paarl, Robertson, Stellenbosch, Worcester and Breedekloof

(Figure 2.4). Paarl has the most hectares of Chenin blanc vineyard plantings (17%), followed by Malmesbury (16%), Breedekloof (15%) and Olifantsfiver (15%) as indicated in Table 2.1.

The annual competition, the Chenin Blanc Challenge, was instituted by the South African Wine magazine in 1996 to raise the awareness of Chenin blanc wine quality. The competition results showed that wines from certain areas performed exceptionally well in receiving four stars or more out of a possible five, over the last four years. In 2009, 53% of the best wines came from the Stellenbosch area (Winemag, 2009). In 2010, eleven wines showed exceptional quality which included 10 (91%) Stellenbosch wines (Winemag, 2010). In the following year, 46% top performing wines originated from Stellenbosch (Winemag, 2011). Most recently, at the 2012 Chenin Blanc Challenge, 50% of the wines were from Stellenbosch (Winemag, 2012).

The profiling tasks undertaken in this study are particularly relevant in the context of regionality. Regionality can defined as the reputation for a wine region has for producing distinctive wine style (Easingwood, 2011). It was therefore important to investigate if there are significant differences between chemical and sensory properties of Chenin blanc wines produced in the different wine growing areas mentioned above. Profiling will also help to identify and confirm if there are regions that consistently produce Chenin blanc wines of exceptional quality. It is also important to investigate if the typicality of Chenin blanc that can be associated with a specific region. Typicality has been defined as product properties that are representative for a product category. The perceived representativeness of wines that belong to a category can be influenced by sensory and chemical properties that are directly dependent on the environment, viticultural and oenological factors. A wine that is typical for a certain category is regarded as a good example of the concept and considered more typical (Cadot *et al*., 2010).

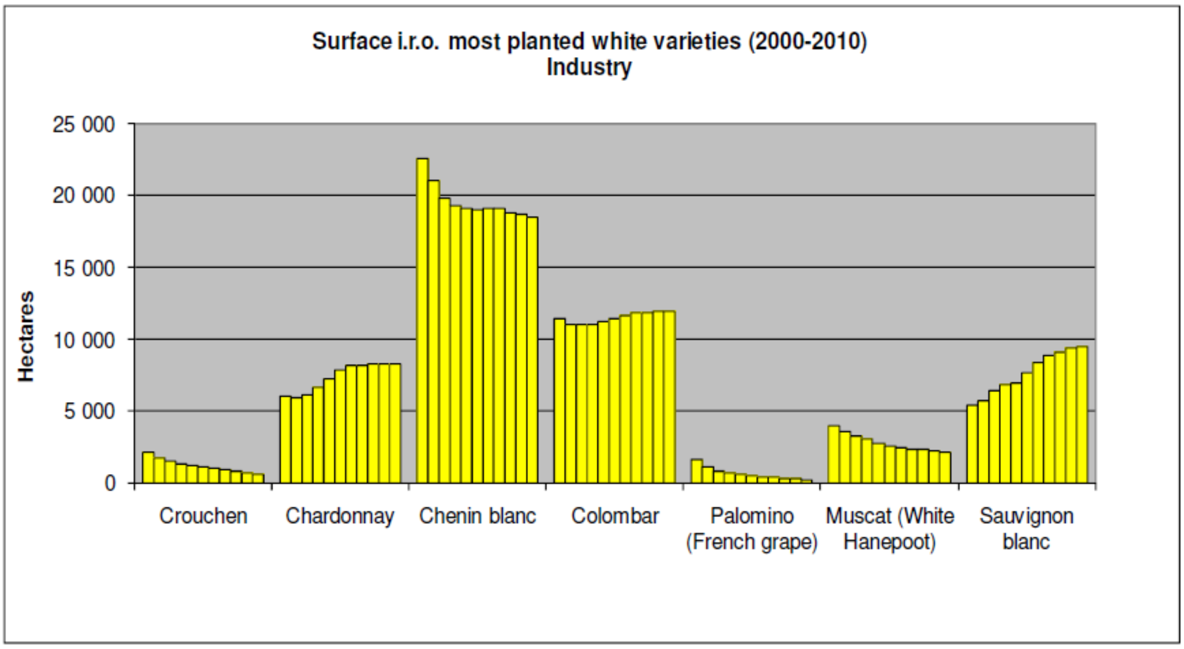

Figure 2.3 Surface in hectares in relation of (i.r.o.) most planted white varieties in South Africa (2000-2010). Used with permission from SAWIS, 2011.

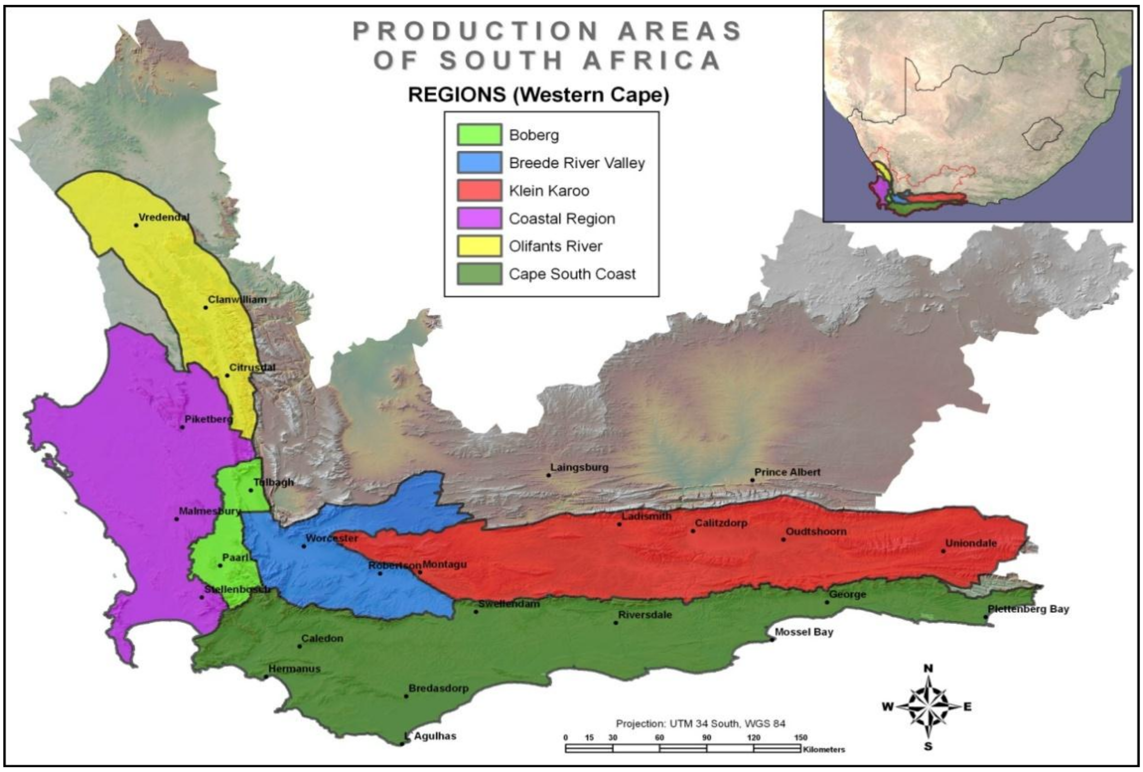

Figure 2.4 Wine production areas of South Africa. Used with permission from SAWIS, 2012.

Table 2.1 Hectares of wine grape varieties per region in South Africa for 2011. Used with permission from SAWIS, 2012.

VARIETY	TOTAL HECTARES	HECTARES IN WINE AREA AS % OF VARIETY TOTAL								
		ORANGE RIVER	OLIFANTS RIVER	MALMES-BURY	LITTLE KAROO	PAARL	ROBERT-SON	STELLEN-BOSCH	WORCES-TER	BREEDE-KLOOF
Chenin blanc	18 326	6	15	16	3	17	9	8	11	15
Colombar(d)	11 857	22	21	2	7	4	19	1	9	16
Sauvignon blanc	9 644	0	6	13	1	11	18	30	11	10
Chardonnay	8 092	1	5	11	2	16	27	14	11	13
Muscat d'Alexandrie	2 084	10	21	2	10	5	6	3	10	34
Sémillon	1 193	-	6	11	0	13	8	15	12	34
Viognier	881	2	4	17	2	27	10	18	11	9
Muscat de Frontignan (Muscadel)	676	4	9	2	9	9	55	3	7	1
Other white varieties	3 173	12	8	9	3	13	18	10	13	14
Total white varieties	**55 927**	**8**	**13**	**11**	**4**	**12**	**16**	**11**	**11**	**15**
Cabernet Sauvignon	12 104	1	4	18	1	23	12	29	5	7
Shiraz	10 321	1	9	19	1	22	11	22	7	8
Pinotage	6 535	1	9	25	1	20	9	19	5	12
Merlot	6 416	1	6	14	2	18	11	33	6	10
Ruby Cabernet	2 193	6	14	6	4	7	30	2	9	22
Cinsaut	1 980	-	2	18	0	38	4	7	5	27
Pinot Noir	1 019	0	4	4	2	15	22	27	23	3
Cabernet Franc	910	0	1	11	0	20	4	48	9	6
Other red varieties	3 162	1	5	23	5	22	11	19	6	7
Total red varieties	**44 641**	**1**	**7**	**18**	**2**	**21**	**12**	**24**	**6**	**10**
Total	**100 568**	**5**	**10**	**14**	**3**	**16**	**14**	**17**	**9**	**13**
Sultana (Hectares)	8 350	7 605	184	197	32	90	32	1	204	5

2.1.5.2 International perceptions of South African Chenin blanc wine quality

In the last decade, Chenin blanc has received more and more attention with producers moving away from bulk production and focusing increasingly on quality wines (Budd, 2002). In 2003 the first Rendez-Vous competition was launched in the Loire Valley (Budd, 2003) and Chenin blanc wines from all over the world were compared. The event was designed to raise the image of Chenin blanc wine by addressing the style diversity of this cultivar. South Africa entered 25 wines and 12 of these, were selected to form part of the final 49 wines that according to the judges, showed the best expressions of Chenin blanc. The following year, 16 South African Chenin blanc wines were selected to form part of the 51 “great expression” wines (Winemag, 2004). South African Chenin blanc is making international headlines with wine experts that are “singing the praises of top local Chenins” (Peridot Communications, 2010). The latter news article also reported that leading UK wine journalist, Tim Atkin, highlighted the positive improvement of “Cape Chenins” and included four South African Chenin blanc wines in his list of recommended wines. In 2011, at the International Wine Challenge competition, two South African Chenin blanc wines received gold medals (Eedes, 2011). These competition results showed that the quality of some South African Chenin blanc wines is on par with the best in the world.

A renewed interest in Chenin blanc’s potential started in the 1990’s when the Chenin Blanc Association (CBA) was found (CBA, nd). Prior to this event, Chenin blanc was thought of as a “workhorse variety” in South Africa and was mainly used for the production of brandy and bulk wine blends (CBA, nd). The variety can produce high yields of must per hectare (even up to hundreds of hectoliters) if it receives sufficient irrigation and sunlight, however, these high yields do not result in quality wines (Budd, 2002). It was noted in 2003 (Marais, 2003) that Chenin blanc can produce wines of exceptional quality when the cultivar is cultivated and treated correctly. For dry style quality wines, yields of 40 - 50 hectolitres/hectare are generally accepted. This is also the legal limit for wines produced in Savennières in France (Clark, 2007).

Recently, the question whether Chenin blanc can become South Africa’s signature wine variety was addressed by van Casteren (2011), a well-known wine writer and wine educationist in Europe. The phrases “signature” or “reference” wine were defined as a variety that drives the association with that country’s wine category in the first place, and also one that receives great support from the international wine industry. Van Casteren conducted a comparative Chenin blanc tasting in Paarl, South Africa, as well as at Prowein, Germany, between South African and French wines from the Loire Valley. The purpose of the tastings was to determine if South African wines were perceived distinctively from Loire wines, and if the South African wine quality was of high enough standard to qualify as a reference wine. The results showed that South African and Loire wines were distinctively different; however, the quality of South African wines was in no way inferior to that of the Loire wines. According to a survey that Van Casteren conducted on 660 international wine producers for the purpose of this study, Chenin blanc was also considered the most favourable white variety to become South Africa's reference wine.

These findings once again underline the huge opportunity that exists for Chenin blanc, both locally in South Africa and internationally. Apart from the fundamental aspects of the research undertaken in this present MSc thesis, the benefits and potential applications of profiling the chemical and sensory properties of Chenin blanc wines, to support the South African wine industry with the task of establishing this variety, were a driving force in identifying the research objectives of this study.

2.1.5.3 Versatility of South African Chenin blanc wine styles

Chenin blanc is regarded as a neutral variety, that do not have a typical grape-derived character that can be ascribed to specific compounds, such as the monoterpenes in Muscat, Riesling and Gewürztraminer wines (Ugliano *et al.*, 2006) and methoxypyrazines (Lund *et al.*, 2009) or volatile thiols in Sauvignon blanc (Makhotkina and Kilmartin, 2012). However, several impact odourants in Chenin blanc wine evolve during the fermentation process (Marais, 2005a). These fermentation-derived flavours can be manipulated by terroir, viticultural practices (such as vine age, clone type, trellising system and yield) as well as enological practises (such as yeast strain, wood contact, and bottle maturation), as comprehensively discussed in a review on Chenin blanc (Loubser, 2008). Although the focus in this study is not on in-depth viticultural or enological aspects, the importance of viticulture and vinification influences on wine quality (Loubser, 2008) cannot be neglected. Chenin blanc wine quality is influenced significantly by the volatile composition of the wine (Marais, 2005b). Information about the effects of vinification techniques on the quality of Chenin blanc is therefore very important for wine producers and the correct implementation of this knowledge in the cellar can assist further improvement of South African Chenin blanc. This once again emphasises the benefit that profiling of the volatile composition, amongst other compounds, has in the broader context of the research.

Various wine styles that range from dry to sweet, including sparkling wine, are produced from the Chenin blanc grape in South Africa. The six styles and the main criteria used for classification, is the residual sugar (RS) content, as shown in Table 2.2 (CBA, nd).

Table 2.2 The six recognised styles of South African Chenin blanc wine (CBA, nd).

Style	Description
fresh & fruity	less than 9 g/L residual sugar
rich & ripe unwooded	less than 9 g/L residual sugar
rich & ripe wooded	less than 9 g/L residual sugar
rich & ripe slightly sweet	between 9 and 30 g/L residual sugar
sweet	more than 30 g/L residual sugar
sparkling	tank fermented or Cap Classique

Fresh and fruity, rich and ripe unwooded and rich and ripe wooded wines, all containing RS less than 9 g/L, form the bulk of the Chenin blanc export wines, and therefore, these three styles were chosen for this study. Following the label requirements in South Africa, these three styles include wines from extra dry (maximum RS of 2.5 g/L), dry (maximum RS of 5 g/L) and semi-dry (maximum RS of 5-12 g/L) wines (SAWIS, 2012b).

Most Chenin blanc wines are made in a fresh and fruity style, although this tendency is shifting towards more complex styles that show sensory attributes of ripe fruit. The vines are significantly pruned to reduce grape yields. Oak fermentation and maturation are also nowadays being introduced more often to Chenin blanc winemaking in South Africa (CBA, nd). The sensory attributes of these three styles are discussed in detail in the introduction of Part 3.

Fresh and fruity style wines are normally produced from grapes harvested between 21 – 23^{o}Balling (O' Kennedy, 2009). As mentioned before, wine yeasts play an important role in the aroma profiles of Chenin blanc wines and can be used to influence the style of wine (Marais, 2003). The yeast *Saccharomyces cerevisiae* (*S. cerevisiae*) VIN7, are used to produce fresh and fruity wines to promote positive mercaptane flavours (such as guava, grapefruit and passion fruit), while other yeasts are used if an increased production of esters that are associated with tropical fruit salad flavours, is desired. To benefit from the maximum aroma in fresh and fruity wines, the fermentation temperature is kept between 12^{o}C and 13^{o}C. Rich and ripe style wines, without wood contact, are produced from grapes at ripeness levels between 23 – 27^{o}Balling. *S. cerevisiae* yeasts that promote ester formation such as VIN13 (floral, tropical and blossom aromas), NT116 (tropical and citrus aromas) and NT45 (more complex wines with a fuller mouth-feel) are used for this style (O' Kennedy, 2009). Fermentation temperatures normally range between 12^{o}C and 16^{o}C. For the rich and ripe style that receives wood contact, grapes are typically harvested at 25^{o}Balling or higher. VIN13 and VIN7 are used for fermentation and the temperature is kept as low as possible, preferably at 13^{o}C. However, other yeasts can also be used that favour higher fermentation temperatures (O' Kennedy, 2009).

Its versatility has been considered as a positive attribute of Chenin blanc wine, with quality wines that are available from the very affordable price category to extremely expensive wines (Eedes, 2011) and the various styles can be combined with food to make some exceptional food and wine pairings (Heyns, 2009).

2.1.6 Conclusions

With the evidence that the quality of Chenin blanc is rising and has the potential to become the variety that is associated with South Africa internationally, it has become a matter of great importance to profile Chenin blanc wines. This entails the establishment of ranges for the volatile aroma compounds, non-volatile compounds and other basic wine parameters. Chemical profiling is discussed in Part two of this literature review, while sensory profiling is discussed in part three.

2.2 Part 2: Chemical profiling of wine with specific focus on Chenin blanc

2.2.1 Introduction

A chemical profile of a wine provides an overview of its chemical composition. An understanding of the chemical composition, especially the volatile composition, offers the potential to evaluate the aroma of a variety and to possibly improve the wine aroma quality (Marais, 2005a). Furthermore, the quantified chemical composition could be very useful for authentication purposes, as well as for certification of some quality categories, such as mono-varietal wines, vintage aspects and production area. The chemical profile is also used in studies that investigate the metabolism of different yeasts and the effects of vinification techniques on the metabolic profile.

The most important compounds responsible for wine flavour derived from grapes are terpenes, organic acids and various glycosylated precursors of volatile compounds in the final wines (Lund and Bohlmann, 2006). Other compounds that arise in the wine can originate from yeast and bacterial metabolism (Francis and Newton, 2005). Studies that have investigated the effect of yeast strain includes a study done by Loscos *et al.* (2007), who found that the chemical compounds responsible for aroma, were dependent on the yeast strain used for winemaking. Torrens *et al.* (2008) also demonstrated that different yeasts strains effect the final concentrations of esters, some which are responsible for fruity character notes in wine.

Malolactic fermentation (MLF) has been widely applied in winemaking and is known to de-acidify the wine by converting L-malic acid to L-lactic acid (Augagneur *et al*., 2007). MLF modifies the flavour profile of wine and adds to microbial stability (Bartowsky, 2005). Cejudo-Bastante *et al.* (2011) investigated pre-fermentative skin maceration in combination with hyperoxygenation. The results showed an increased content of fatty acid esters and terpenes that resulted in an improvement of tropical fruit flavours combined with a fuller mouth-feel.

Chemical compounds can also be extracted from oak during wine ageing and chemical reactions that occur during storage of the wine (Francis and Newton, 2005). Pérez-Serradilla and Luque de Castro (2008) reviewed the role of lees in wine production. Lees contact releases a number of compounds into the wine that forms complex balances with fermentation-derived volatiles. The concentrations of esters responsible for fruity aromas decreased depending on the amount of lees and longer contact times. During ageing of wine in barrels, Ortega-Heras *et al.* (2004) found that the volatiles that are extracted from the wood are dependent on the grape variety used. Furthermore, it was also found that the changes in volatile composition could be used to correctly classify the wines according to the wood contact time received.

To our knowledge, only limited research regarding the chemical profiling of South African Chenin blanc wine has been done, and results have been reviewed by Marais in 2003. To date, only small numbers of selected wines were used, which, although useful for the purpose of the original investigations, do not allow any conclusions to be drawn from the varietal as a whole. Most of the chemical studies focused on chemical compounds present in Chenin blanc grapes before fermentation such as the work presented by Augustyn and Rapp (1982), who identified compounds present in the grapes during different maturity stages.

Studies that focused on the chemical compounds of Chenin blanc include the investigation of the effect of bottle maturation on wine quality by Marais and Pool (1980). The study found that an increase in storage temperature results in a decrease in ester content and an increase in dimethyl sulphide. In the following year, Du Plessis and Augustyn (1981) investigated the presence of 4-methyl-4-mercaptopentanone in Chenin blanc wine. These authors suggested that the compound may act to contribute to the “guava” character often associated with Chenin blanc. A more recent study focussed on the contribution of inoculated yeast strain and lees contact on Chenin blanc wine quality (Marais and Jolly, 2005). This study focused on the grapes of one farm and documented the total acetate esters, total ethyl esters and total higher alcohols, as well as sensory data obtained from wine tastings.

Neutral cultivars mostly rely on flavours derived during the fermentation process (Marais, 2005a). Therefore, it can be expected that the fermentation-derived compounds have a definitive influence on the final wine aroma character of Chenin blanc, although this aspect needs to be investigated. The main chemical groups of volatiles (responsible for aroma) and non-volatile (responsible for taste and mouth-feel) are discussed in the following sections.

2.2.2 Fermentation-derived compounds

Hundreds of aroma compounds have been identified over decades of wine flavour research (Rapp, 1995; Ortega-Heras *et al.,* 2002) and the more than 1000 compounds that have been recognised to date (Roland *et al.*, 2012), prove the chemical complexity of wine. Wine aroma is not the result of single aroma active compounds in isolation, but is rather due to the various interactions between specific aroma compounds (Fischer, 2007). These interactions give rise to a wine's taste and aroma (Dall'Asta *et al*., 2011).

The amino acids in grape musts are important precursors, as these compounds are converted by yeasts to volatile compounds, thereby contributing to the final wine aroma. Amino acid profiles vary significantly amongst wine varieties and during grape ripening (Fischer, 2007). During alcoholic fermentation, yeasts convert grape sugar into ethanol and carbon dioxide and this process gives rise to a wide range of volatile metabolites. These yeast-derived volatile compounds include, amongst others, esters, higher alcohols and fatty acids (Stashenko *et al*., 1992; Lambrechts and Pretorius, 2000; Delfini *et al*., 2001). These classes of volatile compounds are also the most abundant in wine (Fischer, 2007).

Esters are produced by yeast metabolism and are related to pleasant, fruity and floral aromas. The most important esters include isoamyl acetate, ethyl hexanoate and 2-phenyl acetate (Lambrechts and Pretorius, 2000). Higher alcohols contribute to wine flavour with solvent–like, marzipan and floral aromas (Francis and Newton, 2005) and add to the complexity of wine under 0.3 g/L. At higher concentrations, these compounds are perceived as having a pungent smell (Lambrechts and Pretorius, 2000). This group includes methanol, ethanol, propanol, isobutanol, butanol, isoamyl alcohol and 2-phenyl ethanol. Most important fatty acids present in wine include acetic, hexanoic, octanoic and decanoic acids. These compounds can positively contribute to the wines in small concentrations, but at higher concentrations cause unpleasant rancid, cheesy and even vinegar-like rancid odours (Lambrechts and Pretorius, 2000; Francis and Newton, 2005).

Esters, alcohols and fatty acids are present in all wine cultivars, although in different concentration levels relative to each other. This gives rise to a synergy between them, giving a specific wine its unique flavour (Swiegers *et al.,* 2005). It is thus possible to use these volatile compounds to investigate differences between cultivars or wine styles (Ferreira *et al*., 2000). Studies have been where these chemical compounds were used to differentiate between different wine producing areas (Marais *et al*., 1981b; Oliveira *et al*., 2005; Gil *et al.,* 2006; Louw, 2009; Vilanova *et al.,* 2010), vintages (Miranda-López *et al*., 1992; Chrisholm *et al*, 2005), varieties (Marais *et al*., 1981a; Lopez *et al*., 2003; Câmara *et al*., 2006b; Weldegergis *et al.,* 2011) and wine styles (Rodríguez-Nogales *et al*., 2009; Dall'Asta *et al*., 2011).

2.2.3 Terpenes and related compounds

Terpenes, including monoterpenes, sesquiterpenoids, and C13-norisoprenoids, can contribute to floral, fruity and perfume odours in wine. The most important monoterpenes are geraniol, linalool, nerol and α-terpineol (Marais, 1983). Monoterpenes are regarded as typical grape varietal character impact odourants, mostly in floral varieties such Muscat and Gewürztraminer (Fischer, 2007).

Monoterpenes have been detected in a large number of white wine varieties, usually under their perception thresholds, but these compounds can contribute to the overall complexity through interactions amongst compounds (Rapp, 1995). Higher concentrations of monoterpenes can result from fermentation conditions that stimulate the glycolytic flux, such as high yeast assimilable nitrogen content in the must and aerobic fermentation. During wine maturation, terpenes can be oxidised that results in lower concentrations in the aged wine (Rapp, 2005).

2.2.4 Organic acids

Organic acids greatly contribute to a wine's composition and organoleptic qualities (Ribéreau-Gayon *et al.*, 2006). These compounds also bring stability to wine due to their preservative properties. This significantly contributes to an increased ageing potential. The main organic acids present in grapes include tartaric-, malic- and citric acids. These three acids are responsible for the majority of acidity in grapes. However, organic acids are also produced and metabolised during fermentation. Pyruvic-, lactic-, succinic-, acetic-, citric-, malic-, oxaloacetic-, and fumaric acids are all regarded as the main fermentation-derived organic acids (Ribéreau-Gayon *et al.*, 2006).

Tartaric acid and malic acid are the most abundant organic acids in wine that significantly contribute to the pH of a wine (Liszt *et al*., 2012). MLF involves the conversion of malic acid to lactic acid by lactic acid bacteria (LAB) and results in de-acidification of wine, as well as alteration of the aroma (Augagneur *et* al., 2007). Controlled MLF increases the microbial stability of the wine (Lonvaud-Funel, 2010). Fresh and fruity and rich and ripe unwooded Chenin blanc wine styles usually do not undergo MLF, however, rich and ripe wooded wines often go through partial MLF with incomplete conversion of malic to lactic acid in the barrel. These changes contribute positively to the complexity and mouth-feel of the wine, however, when MLF is 100% completed, it is possible that the delicate flavours of Chenin blanc may be masked (O'Kennedy, 2009). Gluconic acid concentration is influenced by noble rot, a condition that is often found on Chenin blanc grapes (Ribéreau-Gayon *et al.*, 2006).

2.2.5 Other compounds that could make a significant contribution towards Chenin blanc wine flavour

Several other compounds, not analysed in this study, but that could have a significant influence on the flavour of Chenin blanc wines, are the phenolic compounds and volatile thiols. These two classes are briefly discussed here.

Phenolic compounds contribute to the taste characteristics of wine, including astringency, flavour and colour (Lee and Jaworsky, 1987). These compounds also have anti-oxidant properties (Benítez et al., 2002). The concentration of phenolic compounds depends on the grape variety, duration of maceration and the chemical reactions that these compounds undergo during wine ageing (Peña-Neira *et al.*, 2000). Browning in white wine results from oxidation of phenolic compounds to quinines, which then in turn polymerise into macromolecules with a typical yellow-brown hue (Singleton, 1987). Oxidative browning of white wines was shown to be especially related to the flavonol content of the wine.

Volatile thiols (volatile sulphur compounds) are naturally present in grapes in their free form, but also as glycosidically bound, odourless precursors. These are hydrolysed during the winemaking process and contribute to the varietal aroma (Roland *et al.*, 2012). The concentration of volatile thiols in wine depends on the concentrations already present in the specific grape variety and these compounds have been identified in Sauvignon blanc (Roland *et al*., 2010), amongst other cultivars. Specific aromas that are often associated with thiols include fruity notes such as passionfruit, grapefruit, blackcurrant, guava and box tree. These aromas arise from chemical compounds including 4-mercapto-4-methylpentan-2-one (4MMP), 3-mercaptohexan-1-ol (3MH) and 3-mercaptohexyl acetate (3MHA) (Roland *et al*., 2012). In a recent study by Makhotkina and Kilmartin (2012) it was found that concentrations of 3MHA, amongst other compounds, decreased during wine storage due to hydrolysis reactions. A historical study by Du Plessis and Augustyn (1981) suggested that 4MMP may contribute to the guava flavour in Chenin blanc. However, it is evident that limited or no recent studies were undertaken with regards to Chenin blanc and the volatile thiols, and these compounds may play an important role in the aroma of this cultivar.

2.2.6 Quantification of volatile compounds

The general methods in most of studies aimed at quantification of the volatile compounds are gas chromatography that can be coupled to a flame ionisation detector (GC-FID) or mass spectrometry (GC-MS). GC-MS methods generate rich untargeted chemical fingerprints of wine that can be used for discrimination studies (Gil *et al.,* 2006). Other characterisation studies included the analysis of phenolic compounds and organic acids (Kerem *et al*., 2004) and elements present in wine (Minnaar *et al.*, 2005).

GC-FID is a very suitable method for volatile analysis due to the wide linear concentration range and high sensitivity and response to these compounds (Gil *et al.,* 2006). However, this method requires reference standards to identify the compounds present in the wine (Reineccius, 1998).

Volatiles in wine are present in a wide range of concentrations and a sample preparation step is necessary to extract and concentrate these compounds prior to analysis. Several extraction methods are available for the sample preparation step. The method that is preferred for the recovery of volatile compounds in wine is liquid-liquid extraction that involves an organic solvent. Solid phase extraction (SPE) and solid phase micro-extraction (SPME) are methods used to purify and enrich samples before analysis (Castro *et al.,* 2008). In the case of SPE, the sample is passed through a column fitted with chromatographic packing. When the sample passes through this cartridge, solutes with an affinity for the chromatographic phase will be retained. The phase is then rinsed with a suitable solvent to remove impurities and thereafter the solutes of interest are eluted. SPME does not use organic solvents and the solutes are retained by a specific layer that is coated onto a fused-silica fibre.

2.2.7 Conclusion

Wine flavour is significantly influenced by hundreds of chemical compounds which can be grape-derived, fermentation-derived or are formed during ageing and storage (Fischer, 2007). To our knowledge, mostly dated and limited research regarding the chemical profiling of South African Chenin blanc wine has been done. Indeed there is no published work that report on detailed profiling of the different styles of Chenin blanc.

There is a clear need for a comprehensive survey of the chemical profiles of Chenin blanc and one of the major objectives in the research design of this master thesis, was to initiate this process through focussing on the fermentation-derived volatiles. The data generated need to be added to the Winetech database that was established in 2009 and already includes the aroma profiles of the white cultivars Chardonnay and Sauvignon blanc, and red cultivars Cabernet Sauvignon, Merlot, Shiraz and Pinotage (Louw *et al.,* 2009). This data are considered as a chemical fingerprint of the mentioned cultivars and can be used for benchmarking and authentication purposes. The data on the volatile profile of Chenin blanc wine may further be useful to predict wine styles and to protect the style concept. The volatile profile can also be used to investigate differences over vintages and between wine production areas.

2.3 Part 3: Sensory evaluation of wine

2.3.1 Introduction

Wine flavour is the result of complex combination of various chemical and microbiological interactions amongst hundreds of compounds for each specific wine (Rapp, 1998; Noble and Ebeler, 2002). Flavour can be described as a combination of taste and aroma attributes in a product (Marias, 1983). Identification and quantification of products' sensory characteristics are very important for industries and are used as criteria to monitor the quality of products (Chollet *et al.,* 2011). This scenario is not least so for the wine industry.

According to the style classification given by CBA, young fresh and fruity Chenin blanc wines should have fresh fruit salad and floral aromas. Fruit salad flavours include apple, melon, apricot, guava and pineapple. All of these flavours should ideally be backed by a firm, crisp, natural acidity that should give a balanced palate. With wood contact, the flavours get more complex with a richer mouth-feel. Bottle maturation results in Chenin blanc wines with a colour that deepens to straw-gold. Palette attributes that are added to wooded wines include aromas associated with nuts and honey.

However, feedback from a leading SA retailer, pointed out that the versatility is also perceived as a negative point, since it leaves consumers confused with not knowing what to expect from the flavour of a Chenin blanc wine, if the style is not clearly indicated on the back label of the bottle (Brower, 2009). There is also the problem that there are no defined guidelines for the definition of each style classification. The result is that producers can label their wines according to any of the styles that they believe will enhance their profit. This leads to even more confusion amongst consumers (Marston, 2011). These aspects could clearly jeopardise the drive towards enhancing the international image of SA Chenin blanc wine, particularly in view of the opinion that the success of New Zealand Sauvignon blanc wine, can partly be ascribed to the consistency in quality and style characteristics of those wines (Van Casteren, 2011). The question arises if there are indeed three clearly distinguishable wine style profiles, FF, RRUW and RRW of Chenin blanc and whether consumers (industry experts and novice consumers) can identify these three styles based on sensory perceptions. The sensory profiling techniques, Descriptive Sensory Analysis (DSA) and sorting will be discussed in detail in the following sections.

Descriptive Analysis (DA) is a primary method in food sensory science that allows insight into the complete sensory profiles, including both qualitative and quantitative characteristics of products (Campo *et al*., 2010; Lawless and Heymann, 2010). Descriptive Sensory Analysis (DSA), a generic variant of DA, is the most popular of these techniques to generate sensory profiles for food (Stone *et al*., 1974). However, this method is unfortunately very time consuming, expensive and cannot be considered for screening of large numbers of samples (Chollet *et al*., 2011). Therefore other methods that are less time consuming, have been developed over the years. These methods include free choice profiling (Williams and Lanron, 1984), projective mapping or napping (Risvik *et al*., 1994), flash profiling (Delarue and Sieffermann, 2004) and sorting tasks (Lelièvre *et al*., 2008).

2.3.2 Descriptive Sensory Analysis (DSA)

DSA was develop during the 1970's (Stone *et al*., 1974) and is regarded as the most frequently used descriptive analysis technique to generate sensory profiles and to characterise and describe food products (Chollet *et al*., 2011). DSA has been extensively reviewed (Stone and Sidel, 2004; Meilgaard *et al.*, 2006; Lawless and Heymann 2010) and can be used to generate a complete description of sensory properties for a product.

DSA has successfully been used over the years in wine related studies. Aiken and Noble (1984) used the technique to compare aromas from wines that were aged in glass bottles and oak. De la Presa-Owens and Noble (1997) used DSA to generate sensory profiles for Chardonnay wines that received different temperature treatments. Schlosser *et al*. (2004) found differences between the sensory attributes of Chardonnay wines that were produced in different regions in Canada. Cadot *et al*. (2010) investigated wine typicality related to a specific terroir, with the use of DSA.

The flow diagram in Figure 2.5 demonstrates the main steps of DSA and was compiled based on descriptions provided for this task, by Lawless and Heymann, (2010). The first step is to select a panel and a panel leader to help with the generation and refinement of product descriptors. Secondly, the panel members are trained with reference standards to calibrate them to have the same understanding of an attribute. Thirdly, after the panel is fully trained, the products are evaluated individually by each panel member. Lastly the panel are validated for consistency to determine if the training was effective or not. These main steps are described in detail in the following sections.

Figure 2.5 Flow diagram of the main steps in the Descriptive Sensory Analysis procedure for profiling sensory descriptors of a product.

2.3.2.1 Panel selection and generation of product descriptors

A small number (eight to fifteen) of panellist is selected for training when descriptive analysis is used (Valentin *et al.,* 2012). Panel members are not regarded as wine industry experts, but rather as highly trained consumers (Perrin *et al*., 2007). The panel receives the entire range of products and can be asked to generate their own terms to describe the products, or they can receive a list of descriptors on the basis of which the wines are evaluated. A combination of these two techniques can also be used and a panel can modify an existing list by generating new descriptors, or discarding some on a score sheet, as the training proceeds. Refinement of the definitions of the terms on the score sheet continues until the panellists are satisfied and in agreement of the terms that are used (Lawless and Heymann, 2010).

2.3.2.2 Panel training

Training of the panellists is important to ensure that the panel is calibrated and that members use the generated sensory attributes in the same way, otherwise valid data analysis can be problematic (Næs *et al*., 2010). To assist with understanding of the attributes, the use of reference standards is very useful to anchor the descriptive terms that were generated (Lawless and Heymann, 2010). Descriptive analysis requires a panel leader whose task is to ensure that panellists are comfortable with all the terms and understand the definition of each term.

2.3.2.3 Product testing

After panellists are fully trained, they individually evaluate the products by scoring the intensity of each attribute on a scale that is anchored with the words that were generated during training (Valentin *et al*., 2012). The products are usually labelled with three digit codes and presented in a randomised order. For data analysis purposes, it is best if the wines that are tested are evaluated in triplicate, rather than duplicate (Lawless and Heymann, 2010). This allows that judge consistency can be evaluated, since the primary function of sensory testing is to conduct reliable tests that provide valid data that can be interpreted meaningfully (Meilgaard *et al*., 2006).

2.3.2.4 Data analysis

Lawless and Heymann (2010) mentioned five sets of important qualifying criteria that must be taken into account when descriptive analysis is used: (1) the discriminating ability of the individual panellists; (2) the reproducibility in the sensory evaluations of the individual panellists; (3) the agreement of individual panellists with the panel as a whole; (4) the discriminating ability of the panel; and, (5) the reproducibility of the panel. There are numerous statistical analyses available to investigate these five criteria from the panel data.

PanelCheck (www. Panelcheck.com) is one of the programmes that can be used for the statistical analysis of sensory data. Data generated with this program are generally easy to interpret, because analysis of variance (ANOVA) can be performed on the sensory data. The data from the triplicate sessions are analysed and the significance levels of interaction effects associated with panellists are determined. If the panel is well trained, there should be no significant differences between the effects amongst judges (Lawless and Heymann, 2010). Principal component analysis (PCA) of each attribute representing all the panellists can be used to indicate the agreement amongst panellists for a specific attribute (Dijksterhuis, 1995; Chollet *et al*., 2011).

2.3.3 Rapid low-cost sensory analysis

In the wine industry, the judgements of wine experts are regarded as very important references for wines (Perrin *et al*., 2007). Wine experts perform tastings on a regular basis, for example in wine competitions. They have gained extended knowledge over years of experience with wine. For this reason they are considered as valuable tasters, even if they did not receive extensive training to calibrate them, as is the procedure with DSA (Parr *et al*., 2002). Wine experts have limited availability to form part of extensive studies like DSA, which can take up to a few weeks to several months to complete. In the industry, time is an important factor and results are often needed fast. Thus, over the years other methods that are less time consuming have been developed, such as the sorting task (Lelièvre *et al*., 2008) that is described below. This approach does not require training sessions and permit individually performed tasting sessions by each panel member.

2.3.3.1 The sorting task

The sorting task (Lelièvre *et al*., 2008) or categorisation of samples is a fast and simple method that can be applied to distinguish between groups of similar products. Sorting is based on categorisation that is a natural cognitive process used on a regular basis in everyday life (Chollet *et al.,* 2011). When applied in sensory evaluation, assessors are asked to group products together that they perceive as similar, based on the sensory resemblances. Descriptions can also be added to the groups.

This method was developed in the 1970's where it was generally used for studies of word meanings (Rosenberg and Kim, 1975). Since then, sorting has been applied to complex products including beer in a study by Chollet and Valentin (2001), who investigated the difference between the sorting tasks done by a trained and untrained panel, respectively. This study concluded that untrained panels could perceive the differences between the beers and could describe the differences; however, the descriptors were not as precise as those generated by a trained panel. Lelièvre *et al*. (2008) investigated the validity of the sorting task, which is a very important aspect when it comes to reproducibility of the evaluations. The findings of the investigation showed that a sorting task followed by a description of the products, provided a trustworthy method by which an understanding can be gained of how the untrained panel perceive a set of products.

The sorting task has also been applied in various studies involving wine. Gawel *et al*. (2001) characterised red table wines according to their mouth-feel sensations together with a description of the flavour properties perceived. The study concluded that a trained panel (n = 14 members) and a panel of skilled winemakers (n = 9 members) had similar interpretations of the descriptive terms. Piombino *et al*. (2004) used an inexperienced panel (n = 23 members) to sort 22 wines and concluded that sorting is a successful qualitative and exploratory strategy as a preliminary step when followed by traditional DA. Perrin *et al*. (2007) also found that the results from sorting by wine professionals (n = 12 members) were comparable with results from the descriptive methods by using a trained panel (n = 17 members).

2.3.3.2 Analysis of data obtained with sorting tasks

Sorting data can be analysed with several techniques. Multidimensional scaling (MDS) is one example of a multivariate statistical technique (Abdi *et al.,* 2007) that requires a preliminary step to generate a similarity matrix, by calculating the amount of times that products were grouped together in the sorting task. MDS analyses this similarity matrix and presents the products as points on a map (Abdi *et al.*, 2007). The distances between the points reflect how similar or different samples are from each other. If samples were often sorted together during the sorting task, the points that represent these samples will be close together. If products were rarely sorted together, the points will be further apart (Chollet *et al*., 2011). MDS can be correlated with additional attributes of the products to interpret the dimensions of the plot obtained from MDS (Cartier *et al*., 2006).

Lawless *et al*. (1995) pointed out that the single major negative aspect of MDS analysis is that the similarity matrix in the preliminary step is the sum of all the individual matrices. This results that individual differences, generated by participants, are lost during this step.

DISTATIS is a method that was introduced by Abdi *et al*. (2007) and is a combination of MDS and STATIS (Abdi and Valentin, 2007) for analysing sorting data. The advantage of this method is that it takes all sorting data, generated by each panel member, into account, and is performed directly on all the separate distance matrices that are generated for each panel member. The difference from MDS is that two types of projective maps are generated with DISTATIS, one for the assessors and one for the products, and these can be interpreted the same was as for MDS or PCA maps. The assessors' map is generated by analysis of the similarity of each assessor's distance matrices that represent how the samples were sorted. The product map is generated from a "between product matrix" or "compromise matrix". This matrix is in turn generated from all the assessors' distance matrices (Abdi *et al.*, 2007; Chollet *et al.*, 2011).

2.3.4 Correlation between sensory and chemical data

In addition, however, beyond the scope of this literature review or research objectives, to understand how sensory attributes are influenced by chemical compounds, it is necessary to investigate the correlation between the two sets of data (Francis and Newton, 2005). This is an important part of flavour research (Noble and Ebeler, 2002), since these relationships may help to customise wine styles and influence wine quality (Noble, 1984; Arrhenius *et al.,*1996; Vilanova *et al*., 2010; Biasoto *et al*., 2010; Green *et al.,* 2011).

Most studies rely on chemometrics to investigate relationships between attributes of products. Noble and Ebeler (2002) reviewed the most generally used methods for relating sensory and instrumental data, including PCA, Generalized Procrustes Analysis (GPA) and

Partial Least Squares Regression (PLS). Vilanova *et al.* (2010) used Pearson correlations to investigate the relationships between sensory attributes and chemical compounds and found that the compounds that mostly contributed to fruity aromas were ethyl esters and acetates, whereas floral aromas were positively correlated with monoterpenes in Spanish Albariño wines. These relationships may help to determine the quality of wine. Correlations between sensory and chemical data have been done by various researchers over the years (Noble, 1984; Arrhenius *et al.,* 1996; Biasoto *et al*., 2010; Green *et al.,* 2011).

It is important to keep in mind that compounds present in concentrations below their threshold levels are unlikely to have an individual significant influence on aroma and they do not act as flavourants (Arrhenius *et al*., 1996). These compounds can be used as chemical markers of the aroma attributes that may be the result of a group of compounds that act synergistically. Chemical markers can be used in solving problems that are not answered by sensory analysis, as well as for development of quality control procedures during the production of different wine styles. In terms of flavour analysis, it must be taken into consideration that volatiles can mask the sensory impact of each other while, on the other hand, also act synergistically to produce "new" perceived aromas in wines (Noble and Ebeler, 2002). It is unlikely that one specific compound is responsible for a characteristic aroma and the task of evaluating the contribution of chemical compounds on wine flavour is by no means simple or straightforward.

2.3.5 Conclusion

Chenin blanc is a versatile variety rendering several different wine styles. This aspect is perceived to be confusing for consumers, who reportedly are unsure about what to expect from a certain style. The three wine styles, FF, RRUW and RRW, still need to be characterised in sensory terms and the unique descriptors for each style, if present, must be identified.

Scientific clarification of the distinctive flavours of Chenin blanc wines may provide wine producers with an objective basis to apply the correct information and style descriptors on the packaging label, with the aim to inform the consumer and influence the purchase decision positively.

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Chapter 3

Research results

Characterisation of the volatile aroma composition of South African dry and semi-dry Chenin blanc wine styles

A combination of research chapters 3 and 4 is under preparation for submission to **The South African Journal of Enology and Viticulture**

RESEARCH RESULTS

ABSTRACT

Chenin blanc wine is of great economic importance to South Africa. The aroma profiles of wines produced from the neutral Chenin blanc grape variety are largely determined by fermentation-derived chemical compounds. To date, very little research has been done on the aroma profiles of South African Chenin blanc wine. This lack of information seriously hampers efforts to investigate the factors that determine Chenin blanc wine quality. In this study, 105 commercial Chenin blanc wines that were representative of the major dry and semi-dry wine styles, wine producing areas and the vintage (2006 – 2010) were subjected to chemical analysis with the aim to compare aroma profiles in these different categories. The wine styles investigated were those officially recognised by the wine industry, namely fresh fruity, rich and ripe unwooded and rich and ripe wooded. Major volatiles, terpenes and related compounds were analysed by Gas Chromatography – Flame Ionization Detection (GC-FID). The routine wine parameters that form an important basis of wine classification, pH, titratable acidity (TA), volatile acidity (VA), glucose, fructose, ethanol and glycerol were quantified with an infrared spectroscopy. Analysis of variance (ANOVA) was performed on the data to determine significant differences between categories. Chenin blanc, Chardonnay and Sauvignon blanc has been investigated. Principal Component Analysis (PCA) was used to investigate the relationships between wine styles, vintages and wine producing areas. Results showed some degree of separation between the unwooded styles and the wooded styles, however no separation was observed between the fresh and fruity and rich and ripe wooded styles based on the chemical composition. It was also found that the profiles of the unwooded styles showed huge variation between the two vintages tested and therefore the chemical profile stayed very similar. Most of the volatile compounds did not show significant differences between the wine production areas Wellington and Paarl, Breede River and Stellenbosch. Significant differentiation was observed between volatile compounds of Chenin blanc, Chardonnay and Sauvignon blanc.

Keywords: Chenin blanc, chemical profiling, volatile compounds, wine styles

3.1 INTRODUCTION

Wine flavour is an important quality determining factor and is the result of interactions between a multitude of chemical compounds. More than 800 chemical compounds have been identified in wine (Ortega-Heras *et al.,* 2002) and these can be derived from the grapes, or originate during fermentation, maturation and storage (Rapp, 1998; Polášková *et al.*, 2008; Ebeler and Thorngate , 2009). The vinification processes influence the concentrations of amongst other, volatile compounds such as higher alcohols, esters, aldehydes, ketones and terpenes and terpene related compounds, all of which that have an important impact on wine aroma (Marais, 2005b). Wine flavour is perceived by taste and aroma (Francis and Newton, 2005) and both volatile and non-volatile compounds are therefore important in determination of the sensory effects (Noble and Ebeler 2002; Biasoto *et al.,* 2010).

Several recent wine profiling studies focussed on aroma compounds (Gil *et al.,* 2006; Vilanova *et al.,* 2010). In addition, the application of multivariate statistical techniques to chemical data has been carried out successfully to investigate the differentiation between wines based on their chemical composition. Louw *et al.* (2009) used Principal Component Analysis (PCA) in a classification study of South African young wine cultivars. Dall'Asta *et al*. (2011) also used PCA to differentiate between the volatile composition of the same wine but from different brands.

Several studies have also been devoted to investigate the differentiation between different factors in wines using volatile compounds over the years. Marais *et al*. (1981a) could successfully distinguish between Colombar and Chenin blanc from different South African wine producing areas using volatile aroma compounds. Marais *et al*. (1981b) also found the same result for Pinotage and Cabernet Sauvignon. Ferreira *et al*. (2000) quantified 30 volatile compounds that were significantly different between four red wine cultivars. Câmara *et al*. (2006b) identified compounds to be significant in aged Madeira wines that can be used as ageing wine markers. Rodríguez-Nogales *et al*. (2009) used the volatile composition to correctly classify between Spanish Verdejo and Sauvignon blanc wines as well as the different styles that included barrel-fermented and barrel-aged wines. Louw *et al.* (2009) found significant differences between the volatile composition of white wines specifically for 2-phenylethanol, ethyl acetate, isoamyl acetate, isoamyl alcohol, butyric acid and isobutyric acid.

Chenin blanc, being the most planted grape in SA is versatile and can grow in many different *terroirs,* leading to the production of several different styles of wine, all bottled under the Chenin blanc label after certification by the Wine and Spirit Board (SAWIS, 2010). These wine styles include three dry and semi-dry styles, i.e. fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW), as well as slightly sweet, sweet, noble late harvest and sparkling styles (CBA, nd).

Chenin blanc flavour mostly rely on flavours derived during the fermentation process (Marais, 2005a; Loscos *et al.,* 2007) The latter can be influenced by various factors including viticultural aspects such as vine age, clone type of variety, trellising system and yield (or crop load), as well as oenological practises such as yeast strain used for alcoholic fermentation, duration of lees and wood contact, and bottle maturation. These factors influence Chenin blanc wine quality as reviewed by Loubser (2008).

Cejudo-Bastante *et al.* (2011) investigated pre-fermentative skin maceration in white wine, in combination with hyperoxygenation and noted an increased content of fatty acid esters and terpenes combined with a fuller mouth-feel. Yeast strains have been shown to have a significant effect on wine aroma by Loscos *et al.* (2007) and Torrens *et al.* (2008) who found that the chemical components responsible for aroma was dependent on the yeast strain used for winemaking. Augagneur *et al*. (2007) confirmed that malolactic fermentation (MLF) de-acidifies wine and thus modifies the flavour profile. Pérez-Serradilla and Luque de Castro (2008) reviewed the role of lees contact in wine production. The authors found that lees contact release a number of additional chemical compounds into the wine that forms complex balances with fermentation derived volatiles to form complex balances of aromas. Ortega-Heras *et al.* (2004) found that the volatiles that are extracted during ageing in barrels are dependent on the grape variety used. Furthermore this study found that the changes in volatile composition could be used to correctly classify the wines according to the wood contact time received.

A study of the literature show that limited research has been done with a representative sample set of Chein blanc with different wine styles for the purpose of chemical profiling. The issues related to the differences of between Chenin blanc regionality, vintage effects and comparison of the profile with Chardonnay and Sauvignon blanc.

Marais (2003) published an overview of Chenin blanc research over the years. These studies mainly focused on chemical compounds present in Chenin blanc grapes before fermentation. Most of these studies were done about three decades ago including the study by Augustyn and Rapp in 1982. This study only identified compounds present in the grapes during different maturity stages from different areas, and did not focus on fermentation derived volatiles.

Studies that focused on the chemical composition of Chenin blanc include the investigation of the effect of bottle maturation on wine quality (Marais and Pool, 1980). The study concluded that the development of a maturation bouquet showed a positive correlation with an increase in dimethylsulphide concentration. Du Plessis and Augustyn (1981) investigated the presence of 4-methyl-4-mercaptopentanone and suggested that this compound may act to contribute to the "guava" character often associated with Chenin blanc.

A more recent study on South African Chenin blanc is the effect of yeast strain and lees contact on wine quality by Marais and Jolly (2005). This study only focused on the grapes from one farm and documented only the total acetate esters, total ethyl esters, total higher alcohols, and sensory data from the wine tastings in terms of different yeasts used.

None of the above studies included a representative sample set of different styles, areas and vintages for the purpose of profiling. Marais *et al.* (2005c) investigated the effect of viticultural factors such as berry size, sunlight exposure and ripeness level of Chenin blanc on the quality of the final wine. The study concluded that the optimum ripeness level is when sugar levels are between 21^{o}B and 24^{o}B. Furthermore smaller berries, containing higher concentrations of aroma compounds and precursors thereof, produced higher quality wines. This study also suggested that grapes ripen under indirect sunlight produce higher quality wines and recommends that direct sunlight on the grapes should be avoided.

The most recent review focussing on Chenin blanc was done by Loubser in 2008. This review also focused on the viticultural and oenological factors that influence Chenin blanc quality and did not include chemical profiling. Louw *et al.* (2009) established an extensive aroma database, in association with Winetech that included the important cultivars of South Africa (Marais, 2007). The database includes 103 Sauvignon blanc, 70 Chardonnay, 62 Pinotage, 89 Shiraz, 89 Cabernet Sauvignon and 83 Merlot wines. However, Chenin blanc has not been included in this database

This study is the first to establish ranges for the major volatile aroma compounds, non-volatile compounds and other basic wine parameters (such as ethanol, pH, sugars, and organic acids) for the profiling of Chenin blanc. The differentiation between the volatile composition of FF, RRUW and RRW wine styles are investigated. Significant differences between the concentrations of major volatiles that exist between these styles will help to identify if these styles are indeed the best way to describe Chenin's diversity.

Investigation of the volatile profile for a specific style of wine is conducted to determine if changes occur during different vintages and if the profile remain the same each year to assign a 'typical" profile to Chenin blanc. The significant differentiation of volatiles between different wine producing areas are investigated. It is of interest to investigate the possibility of regional influences on the chemical profile to access typicality of such wines (Parr *et al*., 2010*).* In this study, the volatile composition of one style (fresh and fruity) was used in an attempt to distinguish between the regionability of different wine producing areas.

3.2 MATERIALS AND METHODS

3.2.1 Wines

A total of 105 commercial wines were sourced from private cellars for the purpose of this study (Table 3.1). Wines were selected to be as representative as possible of the three dry and semi-dry styles FF (43 wines), RRUW (18 wines), and RRW (44 wines). RRUW is not regularly available as the FF and RRW styles in industry. The 2011 John Platter guide for SA wines (Platter & Van Zyl, 2011) was used as a guide to select the Chenin blanc wines that were used. The selection of wines also aimed to be representative of the geographic Chenin blanc production areas in the Western Cape, South Africa. Wines were sourced from all 6 major wine producing areas, namely: a total of nine wines from the Olifants River area, 13 from Breede River, 76 from the coastal region (including Stellenbosch, Paarl, Franschhoek and Wellington areas), one wine from the Walker Bay area, two from the Klein Karoo and four wines from the Overberg area, as shown in Table 3.1. The distribution of the wines in terms of vintage and style is also shown in Table 3.1. Vintages from 2006 to 2010 were included in the study in order to accommodate all three wine styles. FF wines were associated with more recent vintages (2009 and 2010), while the RRUW and RRW wines were generally associated with older vintages (2008, 2009). The chemical profile of these vintages per style was investigated for significant differences over the two consecutive years: 2009 and 2010 for FF and 2008 and 2009 for RRW.

Table 3.1 Vintage and style distribution of Chenin blanc wines used in this study.

vintage	fresh and fruity	rich and ripe unwooded	rich and ripe wooded	total
2006	0	1	1	2
2007	0	2	5	7
2008	2	3	20	25
2009	18	8	18	44
2010	23	4	0	27
Total	43	18	44	**105**

3.2.2 Chemicals, standards and wine simulant

Ammonium sulphate, sodium hydroxide, dichloromethane, absolute ethanol and anhydrous sodium sulphate were purchased from Merck (Darmstadt, Germany). Tartaric acid was purchased from Sigma-Aldrich (St. Louis, MO, USA). Water was purified by a Milli-Q purification system (Millipore, Bedford, MA, USA). Table 3.2 shows the chemicals used in this study together with the supplier and purity. All chemicals, including the internal standards, were of analytical grade and were purchased from Aldrich (Steinheim, Germany), Fluka (Buchs, Switzerland), Riedel de Haën (Seelze, Germany) and Sigma-Aldrich (St. Louis, MO, USA). The internal standards, 4-methyl-2-pentanol (0.5 mg/L) and 2,6-dimethyl-6-hepten-2-ol (0.1 mg/L) were dissolved in synthetic base wine simulant. Synthetic base wine simulant was prepared and consisted of 2.5 g/L tartaric acid and 12 % ethanol dissolved in purified water, as described by Louw *et al.* (2009). The pH was adjusted to 3.5 with 0.1 M sodium hydroxide.

3.2.3 Analysis of major volatile aroma compounds

The procedure used for the analysis of volatile compounds was that described by Louw *et al.* (2010). In brief, wine (5 mL) and internal standard, 4-methyl-2-pentanol, (100 µL of 0.5 mg/L solution in wine stimulant) was extracted with diethyl ether (1 mL) by shaking and sonicating the mixture for five minutes. The mixture was centrifuged at 3600 *g* for three minutes to separate the organic and aqueous layer. The ether layer was dried over anhydrous sodium sulphate, before each extract was injected into the GC-FID instrument in duplicate and analysed as described below.

A J&W DB-FFAP capillary GC column (Agilent, Little Falls, Wilmington, USA) with dimensions 60 m length x 0.32 mm internal diameter (i.d.) x 0.5 µm and a Hewlett Packard 6890 GC (Agilent, Littte Falls, USA) were used for the analysis. The CG was equipped with a split/splitless injector and coupled to a flame ionization detector (FID). Initial oven temperature was set at 33^{o}C for 17 minutes, the temperature then increased by 12^{o}C per minute until the oven reached 240^{o}C for five minutes. When the temperature reached 200^{o}C, 3 µL of the diethyl extract was injected. The split ratio and split flow rate was 15:1 and 49.5 mL/min respectively. The column flow rate was 3.3 mL/min with a total run time of 50 minutes per sample. Hydrogen was used as carrier gas for the samples. The detector temperature was 250^{o}C. When a sample run has finished, a post run of five minutes at 240^{o}C was done to clean the column from any high boiling contaminants. Louw *et al.* (2009) has described the validation of the method in terms of selectivity, linearity, limits of detection and quantification, recovery, robustness and repeatability.

3.2.4 Analysis of terpenes and related compounds

The procedure used for the analysis of terpenes and related compounds has been described by Zietsman *et al.* (2011) and is briefly summarised below. Wine (50 mL) and internal standard, 2,6-dimethyl-6-hepten-2-ol, (50 µL of 25 mg/L in ethanol) were mixed briefly. Solid phase extraction (SPE) was performed in a Visiprep SPE vacuum manifold 20-port model (Supelco, Bellefonte, PA, USA). HF C18 cartridges (Strata SDB-L, Phenomenex, Torrance, CA, USA) were firstly conditioned by rinsing with 4 mL dichloromethane, methanol and wine stimulant (12% v/v ethanol-water mixture) respectively under vacuum. Wine with internal standard was percolated through the cartridge in a drip-wise manner and followed by 4 mL Milli-Q-Water® to flush the cartridge. The cartridge was dried for 15 minutes under vacuum suction. Terpenes were eluted from the solid phase with 2 mL dichloromethane and dried over sodium sulphate. Each extract was injected in duplicate into the GC-FID instrument and analysed as described below.

One microliter of extract was injected into a J&W DB-FFAP capillary GC column (Agilent, Little Falls, Wilmington, USA) with dimensions 60 m length x 0.32 mm i.d. x 0.5 µm with a splitless system for 2 minutes. A Hewllett Packard 6890 GC (Agilent, Littte Falls, USA) injector coupled to a flame ionization detector (FID) was used to carry our GC-FID analysis. The carrier gas was Helium with a flow rate of 30 mL/min. The injector temperature was 220°C and the detector temperature was 250°C. Oven temperature was programmed at 40°C for 12 min, from 40 to 190°C at a rate of 12°C/min, from 190 to 250°C at a rate of 15°C/min, and then held at 250°C for 2 min. The peaks were integrated on HP ChemStation (Rev A.07.01, Hewlett-Packard 1999) software.

3.2.5 Quantification of basic wine parameters

The WineScan FT 120 instrument (FOSS Analytical, Denmark) was used to carry out infrared analysis in die mid-infrared region 5011 to 929 cm^{-1}. The samples were scanned at 40°C using a CaF_2–lined cuvette with a path length of 37 µm. Twenty repeat scans of each sample were collected, and the average spectrum processed, as described (WineScan FT120 Type 77110 and 77310 Reference Manual, Foss Analytical, Denmark, 2001). With this application instrument, these settings are fixed and cannot be changed by the user. In-house calibration models of the Chemical Analytical laboratory of the Institute for Wine Biotechnology, Stellenbosch University, South Africa, were used to predict the routine wine parameters pH, TA, VA, glucose, fructose, ethanol and glycerol. The organic acids quantified by the WineScan were malic-, tartaric-, succinic- and lactic acid predictions.

3.2.6 Data Analysis

After quantification, descriptive statistical measurements including mean and standard deviation were calculated using Microsoft Excel 2007 (Microsoft Corporation, www.microsoft.com). ANOVA was performed with Statistica 10 (Statsoft Inc., www.statsoft.com), followed by a post-hoc Fisher Least Significant Difference (LSD) analysis, to determine significant differences in chemical composition ($p \leq 0.05$) between wine styles, vintages and wine production areas. Data generated were exported to Unscrambler software (version 6.11, Camo ASA, Trondheim, Norway) and PCA was performed on the data.

Tablel 3.2 List of chemical standards and their purity.

chemical class	analyte	supplier	purity (%)
alcohols	methanol	Sigma-Aldrich	>99.9
	propanol	Fluka	>99.8
	butanol	Fluka	>99.5
	isobutanol	Fluka	>99.5
	isoamyl alcohol	Aldrich	>99
	hexanol	Merck	>98
	2-phenylethanol	Merck	>99
	2,6-dimethyl-6-hepten-2-ol	Fluka	>99.5
	4-methyl-2-pentanol	Fluka	>99
acetate esters	hexyl acetate	Fluka	>99
	ethyl acetate	Sigma-Aldrich	>99.7
	isoamyl acetate	Riedel de Haën	>98
	2-phenylethyl acetate	Fluka	>99
fatty acids	acetic acid	Merck	>98
	propionic acid	Fluka	>99.5
	butyric acid	Fluka	>99.5
	isobutyric acid	Fluka	>99.5
	valeric acid	Fluka	>99
	isovaleric acid	Fluka	>99
	hexanoic acid	Aldrich	>99.5
	octanoic acid	Aldrich	>99.5
	decanoic acid	Sigma	>98
ethyl esters	ethyl butyrate	Fluka	>98
	ethyl hexanoate	Aldrich	>99
	ethyl octanoate	Fluka	>99
	ethyl decanoate	Aldrich	>99
	ethyl lactate	Fluka	>99
	diethyl succinate	Fluka	>98
terpenes	α-ionone	Aldrich	>90
	α-terpeneol	Sigma-Aldrich	>99
	β-farnesol	Fluka	>99
	β-ionone	Aldrich	>97
	citronellol	Fluka	>99
	fenchone	Aldrich	>98
	limonene	Fluka	>99
	linalool	Sigma-Aldrich	>99
	linalool oxide	Aldrich	>97
	linalyl acetate	Aldrich	>97
	nerol	Fluka	>99

3.3 RESULTS AND DISCUSSION

3.3.1 Chemical profiles of different Chenin blanc styles

A total of 50 chemical compounds or major wine parameters were considered while investigating the chemical differences between different Chenin blanc styles (FF, RRUW and RRW). ANOVA indicated that 29 from the 50 compounds that were analysed differed significantly at a 95% confidence level ($p \leq 0.05$) between at least two styles of Chenin blanc and are shown in Table 3.3. The values found for these compounds are presented with the minimum, maximum (range), mean concentration per compound and the standard deviation. Letters are used next to the mean concentration of each compound to show the significant differences between styles.

FF wines are associated with younger vintages (2009 and 2010), as these wines do not normally undergo an ageing period. These wines typically have an ageing potential of 12 – 18 months (O'Kennedy, 2009). RRUW wines that do not receive wood contact are usually kept on the fine lees for periods between three to six months. Marais and Jolly (2005) investigated the effect of yeast strain and lees contact on Chenin blanc wine quality and concluded that lees contact enhances mouth-feel and add to complexity of these wines.

RRW wines are generally associated with older vintages (2008 and 2009) due to a maturation period in oak. The rich and ripe styles have an ageing potential between two and even up to ten years (O'Kennedy, 2009).

Winemaking practices affect the chemical composition of the wine, and thus simultaneously, the sensory properties of wines. Changes in the concentration levels of these compounds, during the maturation process, give rise to more complex aromas and are due to the various compounds extracted from the wood to enhance the quality and flavour profile as well as chemical changes occurring during this period (Ferreras *et al*., 2002).
When looking at the various groups of chemical compounds reported in Table 3.3 (esters, alcohols, fatty acids and terpenes) the following was observed: the esters measured seem to follow no specific trend between FF, RRUW and RRW and some in general have very similar concentrations or slightly lower over the three styles with, indicating that various chemical processes are at play here. Exceptions are isoamyl acetate which decreases three fold from FF to RRUW and RRW. The amount of ethyl hexanoate also showed a twofold decrease compared to the other two styles. Ethyl lactate and diethyl succinate is higher in the FFW style, which can most likely be ascribed to malolactic fermentation.

A more specific trend is observed for alcohols: between FF and RRUW the concentrations are very similar, whereas all the alcohols are found to be present at higher concentrations in RRW.

Pertaining to the fatty acids, there is a slight decrease from FF to RRUW and to RRW, except for the iso-acids which exhibit an increase towards RRW.
With regards to the terpenes, most of them show a more significant increase from FF to RRUW, and to a lesser extent between RRUW to RRW, indicating that maturation without the presence of wood has a bigger influence than when wood is present; since when wood is present there seem to be an overall lesser increase. Here an exception is noted for limonene which is present at half the concentration in the RRW than in the other two styles. This is quite surprising, since it is much more likely that these compounds are absorbed by the oak rather than metabolised. Since terpenes have very similar chemical structures one would expect them to behave in a similar fashion.

When the data for the major wine parameters are inspected, the values also stay relatively constant in the three styles, except for lactic acid being higher and malic acid lower is the RRW wines. This can again be ascribed to MLF.

The above findings can however not be interpreted in isolated groups, since wine making and maturation are dynamic processes. For instance, as mentioned earlier, some esters are known for their positive contribution to wine quality with fruity aromas. But when investigating esters it has to be kept in mind that there exists a chemical equilibrium between fatty acids, higher alcohols and their corresponding esters; also of which present with largely different aroma attributes. When wine undergo an ageing period, changes in the concentrations of chemical compounds occur due to a shift towards chemical equilibrium that is influenced by the pH and storage temperature of the wine (Câmara *et al*., 2006a). Terpenes occur in grapes to some extent as their glycocidically bound form, and these bonds can be cleaved during fermentation.

Literature reports concerning Chenin blanc is very scarce and only two reports could be found reporting concentration ranges for volatiles. When comparing these results with work done by Marais *et.al.* (1983) and Bohlscheid *et.al*. (2006) (the latter using grapes from 1997 but from unknown origin) showed that the concentration values of the volatiles agree for all compounds with the exception of ethyl acetate, isoamyl acetate, 2-phenylethyl acetate, butanol and decanoic acid. The reasons for this is unclear but these differences warrant further investigation and validation of methods used.

PCA was performed using the significant volatiles (shown in Table 3.3) to investigate the differentiation between FF, RRUW, RRW wine styles. The loadings plot of the significant major volatiles is shown in Figure 3.1a. The score plot for the three styles is shown in Figure 3.1b. Differentiation between FF (1) and RRW (3) wines were observed. The first two principal components explained only 54 % of the variance in the data. The FF wines are mostly grouped together on the left side of the plot and are highly correlated with isoamyl acetate, decanoic acid, octanoic acid, hexanoic acid, ethyl butyrate and ethyl hexanoate which are in agreement of the ANOVA results presented in Table 3.3. The RRW wines (3) are mostly associated on the right side of the plot and are highly correlated with butanol, 2-phenylethanol, ethyl lactate, isobutyric acid, isobutanol, isoamyl alcohol, ethyl acetate and diethyl succinate as expected from the results in Table 3.3. However, RRUW (2) wines did not show a clear differentiation between FF or RRW styles and seem to overlap between these styles. This suggests that a continuum may exists between the styles from FF wines resulting into RRW wines rather that three predefined groups of wine styles.

Table 3.3 Ranges, mean values and standard deviation (±SD) for significant compounds (p≤0.05) between different styles of Chenin blanc.

	fresh and fruity (n = 43)				**rich and ripe unwooded** (n = 18)				**rich and ripe wooded** (n = 44)			
esters (mg/L)	minimum	maximum	mean	±SD[1]	minimum-	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]
ethyl acetate	52.62	191.71	97.41[b]	30.03	26.45	174.00	86.55[b]	38.77	52.55	222.46	134.38[a]	39.84
ethyl butyrate	0.47	1.02	0.65[a]	0.11	0.55	0.85	0.65[a]	0.07	0.06	0.84	0.56[b]	0.11
isoamyl acetate	0.62	10.35	3.61[a]	2.17	0.25	3.20	1.65[b]	0.98	0.39	3.85	1.35[b]	0.91
ethyl hexanoate	0.07	1.71	0.78[a]	0.42	0.10	1.40	0.79[a]	0.44	0.07	1.45	0.46[b]	0.40
hexyl acetate	0.13	0.94	0.40[a]	0.18	0.12	0.52	0.30[b]	0.14	0.07	0.52	0.32[b]	0.12
ethyl lactate	13.96	86.86	24.78[b]	14.94	16.67	79.1	27.12[b]	14.18	16.43	273.27	82.21[a]	70.97
diethyl succinate	0.78	2.13	1.33[b]	0.31	0.73	1.69	1.27[b]	0.29	0.84	2.23	1.53[a]	0.27
2-phenylethyl acetate	0.34	1.25	0.68[a]	0.20	0.32	0.74	0.54[b]	0.16	0.33	0.78	0.59[b]	0.11
alcohols (mg/L)												
isobutanol	12.34	46.60	25.23[b]	7.87	16.10	51.9	25.11[b]	9.39	15.54	67.69	33.22[a]	10.12
butanol	0.21	1.63	0.90[b]	0.32	0.50	1.67	0.89[b]	0.26	0.49	2.02	1.15[a]	0.37
isoamyl alcohol	132.82	288.75	176.66[b]	30.37	120.5	227.27	167.62[b];	26.40	141.1	260.43	190.22[a]	28.27
2-phenyl ethanol	10.18	44.83	16.48[b]	5.58	11.34	34.69	17.33[b]	5.85	12.42	44.12	22.10[a]	8.31
fatty acids (mg/L)												
isobutyric acid	0.67	1.99	1.25[b]	0.27	0.95	1.75	1.27[b]	0.23	0.90	2.57	1.52[a]	0.31
iso-valeric acid	0.59	7.76	1.80[b]	1.50	1.63	13.22	5.03[a]	4.01	1.49	13.37	6.32[a]	3.70
hexanoic acid	3.59	8.57	5.36[a]	0.92	3.64	6.65	5.13[a]	0.84	2.73	6.52	4.48[b]	0.74
octanoic acid	5.15	11.48	7.41[a]	1.48	3.99	10.26	6.93[a]	1.60	3.58	11.58	5.92[b]	1.39
decanoic acid	1.73	4.29	2.54[a]	0.52	1.74	4.10	2.48[a]	0.54	1.40	4.44	2.12[b]	0.49

Table 3.3 continued Ranges, mean values and standard deviation (±SD) for **significantly** compounds (p≤ 005) between different styles of Chenin blanc.

	fresh and fruity (n = 43)				**rich and ripe unwooded** (n = 18)				**rich and ripe wooded** (n = 44)			
terpenes (µg/L)	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]
limonene	<10.00	64.7	24.17^{a}	18.82	<10.00	70.29	31.78^{a}	23.64	<10.00	48.34	15.95^{b}	12.01
linalooloxide 1	<10.00	18.14	9.87^{c}	3.95	<10.00	28.28	13.42^{b}	6.85	<10.00	28.18	16.77^{a}	5.32
linalyl acetate	<10.00	37.63	16.57^{a}	6.36	<10.00	22.12	14.39^{ab}	4.01	<10.00	24.71	13.96^{b}	3.98
citronellol	<10.00	32.06	12.14^{b}	4.52	<10.00	42.68	17.61^{a}	11.77	<10.00	37.98	14.54^{ab}	7.33
b-farnesol 2	<10.00	26.52	11.63^{b}	3.12	9.79	42.20	13.00^{ab}	5.82	8.74	39.19	14.81^{a}	7.45
b-farnesol 3	<10.00	12.29	10.08^{b}	0.36	10.00	10.45	10.01^{b}	0.36	10.00	28.74	11.40^{a}	3.73
wine parameters												
volatile acid (g/L)	0.28	0.79	0.49^{b}	0.10	0.26	0.75	0.46^{b}	0.12	0.27	0.84	0.59^{a}	0.11
malic acid (g/L)	1.81	4.58	3.27^{a}	0.59	2.54	3.92	3.13^{a}	0.40	0.27	4.54	2.49^{b}	1.13
fructose (g/L)	0.73	6.97	2.34^{b}	1.36	0.72	7.18	1.87^{b}	1.46	0.66	7.30	3.18^{a}	1.92
ethanol (%)	11.24	16.7	13.29^{b}	1.09	12.01	15.34	13.52^{b}	0.85	12.57	15.13	14.03^{a}	0.60
glycerol (g/L)	5.53	8.96	7.03^{b}	0.79	6.03	8.69	7.15^{b}	0.83	5.85	9.83	8.08^{a}	0.81
organic acids												
lactic acid (g/L)	nd[2]	0.67	0.08^{b}	0.16	nd[2]	0.46	0.03^{b}	0.11	nd[2]	2.21	0.48^{a}	0.62

[1]Standard deviation [2]Not detected

Superscript letters (a, b and c) next to the mean value indicate the significant differences between these values per compound. The letter “a” indicates the highest significant concentration. Concentrations with different letters indicate a significant difference whereas the same letter indicates that the concentrations are not significantly different from each other

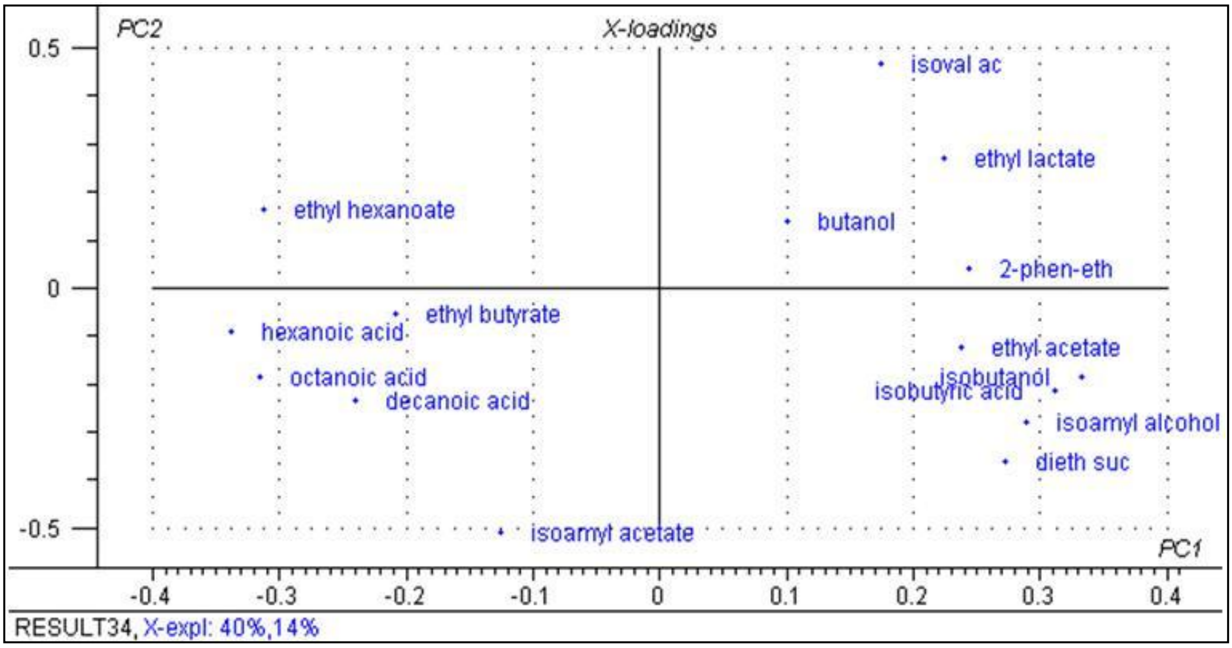

Figure 3.1a Loadings plot of the significant major volatile compounds analysed. Abbreviated names are isoval ac = iso-valeric acid; 2-phen-eth = 2-phenyl ethanol; dieth suc = diethyl succinate.

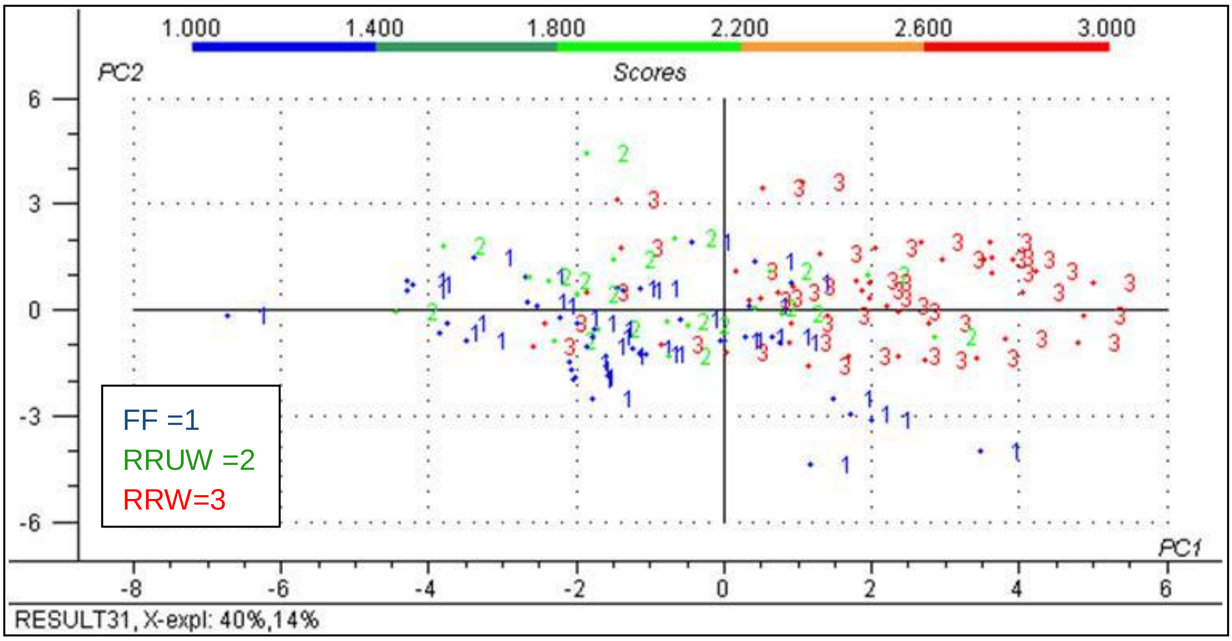

Figure 3.1b Score plot representing the three styles fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW) of Chenin blanc.

In addition the volatile profile for each wine style was investigated with ANOVA to determine consistency over consecutive vintages (years). The overall profile for FF wines form 2009 (n = 18) did not show significant differentiation from the overall profile of FF wines produced in 2010 (n = 23) (data not shown). In the same way, the overall profile for RRW wines in 2008 (n= 20) did not significantly differ from the overall profile of RRW wines produced in 2009 (n = 18). However, since only a small number of RRUW wines were available from a specific vintage it was not enough to make a statistically valid conclusion. In summary, it was concluded that the profile obtained for FF and RRW wines did not change significantly during consecutive years, and the chemical profile obtained for Chenin blanc can be used to describe the typicity of the cultivar.

3.3.2 Differences between Chenin blanc wine producing areas

The volatile composition of fresh and fruity wines originating from different producing areas was compared in order to investigate if characteristic profiles were associated with the different regions. ANOVA of the volatile profiles of the Paarl/Wellington, Breede River and Stellenbosch regions showed that only two esters, namely ethyl acetate and ethyl decanoate, differed significantly between at least two areas. Wines from the Paarl/Wellington region had a higher mean concentration of ethyl acetate, than the other areas investigated. In addition only 4 terpenes showed significant differences namely limonene, linalooloxide, linalool, β-farnesol. These findings are not surprising, since it is common practice that grapes can be sourced from various regions in South Africa, and mixed before fermentation, as well as the blending of different fermented batches, prior to bottling. Weldegergis *et al*. (2011) also investigated the significant characteristics of Sauvignon blanc and Chardonnay wines, between six different regions in South Africa. Only 3 of the 37 volatiles that were determined showed significant differences between regions. Minnaar and Booyse (2004) could not find discriminatory variables to differentiate wines according to three different areas in the Western Cape by measuring basic oenological parameters such as pH, ethanol, volatile acid, total acid, residual sugar, organic acids and glycerol. Minnaar *et al*. (2005) and Coetzee *et al.* (2005) investigated the differentiation between the different wine production areas in the Western Cape by using elemental analysis. These studies were more successful for differentiation between wine producing areas for white wine varieties.

Internationally, it is of interest to investigate the possibility of regional influences on the chemical profiles of wine. In France, protected designation of origin (*AOC*) is used to try and protect so-called *typicality* of wines. The typical character is for instance influenced by the effects of the soil of a specific geographic region (Cadot *et al*., 2010). From the sensory perspective, typicality makes it possible for consumers to differentiate, identify and recognise the wines and it leads to establishment of a firm wine style concept, which is considered a strong positive point for a wine style (Cadot *et al*., 2010). A study by Parr *et al.* (2010) confirmed the distinctive New Zealand wine style "Marlborough Sauvignon blanc" to have a typical Marlborough wine character that was observed in the chemical as well as sensory analysis.

It is important to consider that the wine producing areas used in this study are very large with a range of climatic conditions within an area. The origin of the wines in this study is based on the geographic location of the cellar and is not intended to be representative of an area. Some cellars purchase grapes from other wine producing areas and it is possible that the grapes used for a wine is not from the specified area. Future studies, where the exact geographical region of the Chenin blanc grapes are known, need to be investigated that may facilitate differentiation between wines of different areas. This may contribute to authenticity studies on Chenin blanc wine.

3.3.3 Comparison of volatile composition between white wine cultivars

The concentration ranges, average concentration and standard deviation of the measured chemical compounds in Chenin blanc, has been determined and shown in Table 3.4. Ranges determined for the major volatile compounds (esters, alcohols and fatty acids) were consistent with previous results for white wines reported in literature (Gil *et al*., 2006; Louw *et al*, 2009). The ranges for terpenes and related compounds (data not shown) were also consistent with literature (Marais, 1983; Francis and Newton, 2005) although a large number of wines did not contain detectable limits of terpenes. Terpenes and related compounds are generally referred to as typical grape varietal compounds, for example, Muscat and Gewürztraminer varieties (Fischer, 2007). Chenin blanc is considered a neutral variety that do not contain detectable concentrations of impact odourants in the grape and the specific aroma character mostly rely on volatile flavours derived from fermentation (Marais, 2005a). The majority of these compounds are however present in low free and bound forms in wines, and therefore their quantification can be difficult (Marais, 1983). Augustyn and Rapp (1982) could not detect any measurable concentrations in the berries of Chenin blanc. The ranges for non-volatile organic acids, especially tartaric and malic acids, compared well to those of 11 different white grape cultivars in a study done by Soyer *et al.* in 2003.

As mentioned before, a study by Louw *et al.* (2009) determined the abundance of esters, higher alcohols and fatty acids in young vintage South African Chardonnay and Sauvignon blanc wines. The compounds that differed significantly between these two cultivars were decanoic acid, hexyl acetate and octanoic acid that were higher in the Sauvignon blanc wines. Chardonnay contained higher amounts of ethyl hexanoate. No other significant differences between these two cultivars were observed in terms of the major volatile compounds. These concentrations were used in the present study (Table 3.4) to investigate significant differences with ANOVA between Chenin blanc, Chardonnay and Sauvignon blanc in terms of volatile compounds and basic wine parameters. Statistics showed that all of the 34 compounds that were investigated, differed significantly on a 95% confidence level ($p<0.05$) between at least two cultivars. These compounds are shown in Table 3.4 together with the minimum, maximum, average concentration per compound and also the standard deviation. Different letters are used next to the average to show the significant differences between styles and vintages.

Esters, alcohols and fatty acids were found to contribute significantly to the differentiation of different grape varieties (Ferreira et al., 2000) and studies has used these volatiles to differentiate between wine cultivars. Weldegergis *et al.* (2011) found significant differences between the fusel alcohols of South African Chardonnay and Sauvignon blanc including isoamyl alcohol, propanol, isobutanol and butanol.

In this study, Chenin blanc contains significantly higher concentrations for esters such as hexyl acetate, ethyl lactate, ethyl caprate, diethyl succinate and 2-phenylethyl acetate. Isoamyl acetate concentration was the lowest in Chenin blanc. Chardonnay contained higher concentrations of ethyl butyrate and ethyl hexanoate. Different wine varieties have unique amino acid profiles that give rise to differences in the concentration of these yeast derived compounds (Trinh *et al*., 2010).

Chenin blanc have higher concentrations of the alcohols including iso-butanol, hexanol and 2-phenyl ethanol. Chardonnay contained higher concentrations of propanol and butanol and the lowest concentration of isoamyl alcohol.

It is known even from early studies (Nykänen, 1986) that higher amounts of esters form at lower temperatures whereas higher alcohol concentration increases at higher temperatures. O'Kennedy (2009) confirmed that lower fermentation temperatures favour the formation of acetate esters. This suggest that different fermentation practiced applied to the different grape varieties may be responsible for these variations perceived in the final wines of these cultivars.

In this study, compounds with $R^2 > 0.5$ were used in the PCA plot (Figure 3.2) to investigate the cultivar differences. Chenin blanc was found to be significantly different from Chardonnay and Sauvignon blanc. The first two PC's represents 69% of the total variance of the selected chemical compounds. All the Chenin blanc wines associates on the right side of the first dimension in the PCA and are closely correlated. Sauvignon blanc and Chardonnay associated on the left side of the first dimension and some overlapping can be observed.

It is crucial to take into account that the Sauvignon blanc (n=113) and Chardonnay (n=70) wines used by Louw *et al*. (2009), included young wines that had not undergone an ageing period to eliminate variance that could be caused. The wines that were used to determine the ranges of Chenin included wines from different vintages, wood maturation periods as well as bottel ageing. It is possible that these factors may have an influence on the average values used in this study for differentiation between the cultivars. The effect of maturation on wine is discussed in section 3.3.1.

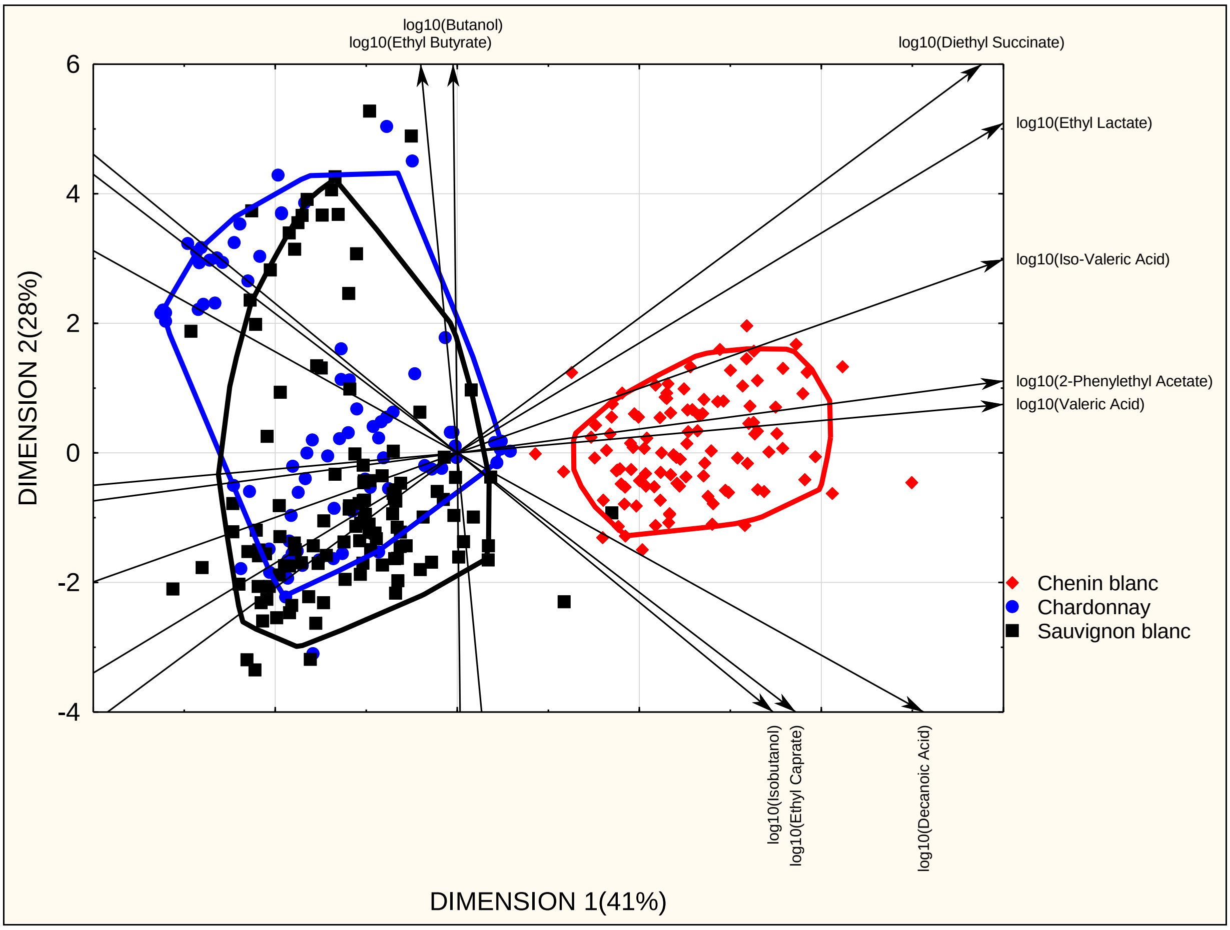

Figure 3.2 PCA score plot showing separation between Chenin blanc, Chardonnay and Sauvignon blanc wines.

Table 3.4 Concentration ranges, mean and standard deviation of chemical compounds in Chenin blanc. Concentrations that was generated by Louw *et al* (2009) for Chardonnay* and Sauvignon blanc* was used to determine significant differences between these three cultivars.

	Chenin blanc				**Chardonnay***				**Sauvignon blanc***			
esters (mg/L)	minimum	maximum	mean	±SD	minimum	maximum	mean	±SD	minimum	maximu m	mean	±SD
ethyl acetate	26.45	222.46	111.04[a]	40.90	20.78	307.51	101.70[a]	35.44	30.22	223.58	90.84[b]	34.33
ethyl butyrate	<0.016	1.02	0.62[b]	0.11	<0.016	1.97	0.73[a]	0.39	0.17	1.73	0.56[b]	0.38
isoamyl acetate	0.25	10.35	2.33[b]	1.89	0.51	14.88	4.32[a]	2.31	1.09	16.24	4.88[a]	2.50
ethyl hexanoate	<0.02	1.71	0.64[b]	0.44	0.31	2.32	1.06[a]	0.50	0.27	1.41	0.72[b]	0.23
hexyl acetate	<0.02	0.94	0.35[a]	0.16	<0.02	1.01	0.10[c]	0.21	<0.02	1.14	0.21[b]	0.25
ethyl lactate	13.96	273.27	49.25[a]	54.62	<0.52	129.34	17.36[b]	22.08	<0.52	42.79	11.48[b]	7.10
ethyl caprylate (octanoate)	0.36	1.38	0.82[a]	0.26	0.16	1.63	0.51[b]	0.22	<0.02	2.58	0.74[a]	0.62
ethyl caprate (decanoate)	<0.07	0.80	0.30[a]	0.11	<0.07	0.43	0.12[c]	0.11	<0.07	0.80	0.18[b]	0.12
diethyl succinate	0.73	2.23	1.40[a]	0.31	<0.03	4.33	0.77[b]	0.69	<0.03	4.89	0.50[c]	0.64
2-phenylethyl acetate	0.32	1.25	0.62[a]	, 0.17	<0.01	0.63	0.12[b]	0.11	<0.01	0.85	0.16[b]	0.14
alcohols (mg/L)												
methanol	54.31	144.30	98.61[a]	15.84	37.98	482	101.00[a]	54.92	21.54	180.47	79.74[b]	30.16
propanol	18.55	84.42	39.58[b]	14.01	20.62	176.56	56.05[a]	25.80	19.20	82.65	36.19[b]	13.77
isobutanol	12.34	67.69	28.56[a]	9.86	2.27	31.61	14.78[b]	9.18	2.26	37.96	16.24[b]	8.02
butanol	0.21	2.02	1.00[b]	, 0.35	<0.06	2.13	1.16[a]	0.40	0.33	2.54	0.94[b]	0.42
isoamyl alcohol	120.55	288.75	180.79[a]	29.79	<0.02	394.93	155.57[b]	44.46	115.40	394.35	178.8[a]	52.16
hexanol	0.95	2.64	1.71[a]	0.33	<0.02	2.73	1.00[c]	0.46	0.13	3.59	1.22[b]	0.58
2-phenylethanol	10.18	44.83	18.98[a]	7.32	5.84	23.80	11.33[c]	2.71	6.89	59.25	13.35[b]	6.17

Table 3.4 continued Concentration ranges, mean and standard deviation of chemical compounds in Chenin blanc. Concentrations that was generated by Louw *et al* (2009) for Chardonnay and Sauvignon blanc was used to determine significant differences between these three cultivars.

	Chenin blanc				**Chardonnay**[*]				**Sauvignon blanc**[*]			
fatty acids (mg/L)	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]
propionic acid	1.45	41.99	3.07^{c}	3.99	<0.22	53.84	14.26^{a}	17.27	1.12	43.01	9.41^{b}	9.16
isobutyric acid	0.67	2.57	1.37^{a}	0.31	0.13	2.28	0.98^{b}	0.42	<0.06	2.74	1.03^{b}	0.42
butyric acid	1.23	3.48	2.15^{a}	0.40	<0.02	4.34	2.05^{a}	0.58	0.78	3.81	1.86^{b}	0.63
iso-valeric acid	0.59	13.37	4.24^{a}	3.68	0.13	1.90	0.85^{b}	0.37	0.15	2.25	0.86^{b}	0.44
valeric acid	0.10	0.57	0.31^{a}	0.16	<0.03	0.40	0.04^{b}	0.11	<0.03	0.37	0.02^{b}	0.06
hexanoic acid	2.73	8.57	4.95^{b}	0.92	<0.02	10.43	5.12^{b}	1.24	3.25	13.70	5.76^{a}	1.76
octanoic acid	3.58	11.58	6.70^{a}	1.60	1.15	9.56	4.51^{c}	2.07	1.73	10.35	6.08^{b}	1.58
decanoic acid	1.40	4.44	2.35^{a}	0.57	0.40	1.96	1.02^{c}	0.45	0.43	3.36	1.42^{b}	0.57
parameters												
pH	2.96	3.81	3.34^{c}	0.13	3.41	4.18	3.70^{a}	0.17	3.14	4.04	3.45^{b}	0.15
volatile acid (g/L)	0.26	0.84	0.53^{a}	0.12	0.24	0.71	0.43^{b}	0.10	0.25	0.76	0.42^{b}	0.11
titratable acid (g/L)	3.86	7.53	6.05^{a}	0.59	4.33	6.33	5.46^{b}	0.38	5.21	7.55	6.15^{a}	0.50
glucose (g/L)	nd[2]	5.59	1.19^{a}	0.99	nd[2]	1.83	0.28^{c}	0.34	nd[2]	4.14	0.70^{b}	0.74
fructose (g/L)	0.66	7.30	2.61^{a}	1.69	0.67	4.26	1.61^{b}	0.85	0.35	5.55	1.64^{b}	0.99
ethanol (%)	11.24	15.34	13.64^{a}	0.93	12.36	15.18	13.83^{a}	0.54	10.38	14.67	12.69^{b}	0.75
glycerol (g/L)	5.53	9.83	7.49^{a}	0.94	5.91	9.88	7.15^{b}	0.67	4.55	11.68	7.05^{b}	1.24
organic acids (g/L)												
malic acid	0.27	4.58	2.92^{b}	0.91	0.39	4.24	2.80^{b}	0.61	1.99	5.80	3.37^{a}	0.70
tartaric acid	1.56	7.23	3.12	1.08	not rep	not rep	not rep	not rep	not rep	not rep	not rep	not rep
succinic acid	0.11	0.99	0.47	0.17	not rep	not rep	not rep	not rep	not rep	not rep	not rep	not rep
lactic acid	nd[2]	2.22	0.24^{a}	0.47	nd[2]	1.19	0.15^{b}	0.26	nd[2]	0.51	0.05^{b}	0.08

[1]Standard deviation [2]Not detected [3]value not reported by Louw *et al*. 2009.

Superscript letters (a, b and c) next to the mean value indicate the significant differences between these values per compound. The letter “a” indicates the highest concentration. Concentrations with different letters indicate a significant difference whereas the same letter indicates that the concentrations are not significantly different from each other.

Chemical composition studies of Chenin blanc is very limited. Marais (2003) published an overview of Chenin blanc research over the years. These studies mainly focused on chemical compounds present in Chenin blanc grapes before fermentation. Most of these studies were done about three decades ago including the study by Augustyn and Rapp in 1982. This study only identified compounds present in the grapes during different maturity stages from different areas, and did not focus on fermentation derived volatiles.

Studies that focused on the chemical composition of Chenin blanc include the investigation of the effect of bottle maturation on wine quality (Marais and Pool,1980). The study concluded that the development of a maturation bouquet showed a positive correlation with an increase in dimethylsulphide concentration. Du Plessis and Augustyn (1981) investigated the presence of 4-methyl-4-mercaptopentanone. These authors suggested that this compound may act to contribute to the “guava” character often associated with Chenin blanc.

A more recent study on South African Chenin blanc is the effect of yeast strain and lees contact on wine quality by Marais and Jolly (2005). This study only focused on the grapes from one farm and documented only the total acetate esters, total ethyl esters, total higher alcohols, and sensory data from the wine tastings in terms of different yeasts used.

None of the above studies included a representative sample set of different styles, areas and vintages for the purpose of profiling. Marais *et al.* (2005c) investigated the effect of viticultural factors such as berry size, sunlight exposure and ripeness level of Chenin blanc on the quality of the final wine. The study concluded that the optimum ripeness level is when sugar levels are between 21^{o}B and 24^{o}B. Furthermore smaller berries, containing higher concentrations of aroma compounds and precursors thereof, produced higher quality wines. This study also suggested that grapes ripen under indirect sunlight produce higher quality wines and recommends that direct sunlight on the grapes should be avoided.

The most recent review focussing on Chenin blanc was done by Loubser in 2008 as a thesis. This review also focused on the viticultural and oenological factors that influence Chenin blanc quality and did not include chemical profiling. Louw *et al.* (2009) established an extensive aroma database, in association with Winetech that included the important cultivars of South Africa (Marais, 2007). The database includes 103 Sauvignon blanc, 70 Chardonnay, 62 Pinotage, 89 Shiraz, 89 Cabernet Sauvignon and 83 Merlot wines. However, Chenin blanc has not been included in this database. The expansion of this database with Chenin blanc data can help with authentication and benchmarking studies for Chenin blanc in the future

3.3 Conclusions

With the evidence that the quality of South African Chenin blanc is rising (Fridjhon, 2009) and have the potential to become the variety that is associated with South Africa (Lloyd, 2011), it became necessary to profile the chemical compounds present in Chenin blanc. However, limited work has been done with a representative sample set of different wine styles for the purpose of chemical profiling. This study is the first to attempt to establish ranges for the volatile aroma compounds, non-volatile compounds and other basic wine parameters (such as ethanol, pH, sugars, and organic acids) for the profiling of Chenin blanc.

The volatile components show a definite differentiation between FF and RRW wine styles, however RRUW wine styles overlap between these wines and tend to form a continuum rather than three distinctively separate styles.

In addition, the significant differences between the different vintages in a specific style were investigated. No overall statistical differences between the FF and RRW wine styles were observed indicating that the chemical profile of these wine styles do not change significantly from one vintage to the next and can be used to describe the typicity of the cultivar.

Most of the volatile compounds did not show significant differences between the wine production areas including Wellington and Paarl, Breede River and Stellenbosch. Volatiles that showed significant differences between al least two areas included two esters, namely ethyl acetate and ethyl caprate. This suggests that future studies should investigate differences between these and other areas with other chemical compounds present in Chenin blanc. Lastly, significant differentiation was observed between volatile compounds of Chenin blanc, Chardonnay and Sauvignon blanc. These ranges that were generated for Chenin blanc volatile compounds were included in the Winetech database consisting of the most important cultivars of South Africa started. The established ranges may aid in authentication studies of mono varietal wines.

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Chapter 4

Research results

Sensory profiling of South African Chenin blanc wine styles

A combination of research chapters 3 and 4 is under preparation for submission to **The South African Journal of Enology and Viticulture**

RESEARCH RESULTS

ABSTRACT

Chenin blanc is seen as an extremely versatile variety that can be used to produce three different dry wine styles, namely fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW). However, no scientific sensory analyses have confirmed these styles of Chenin blanc. Furthermore, the consumers are left confused with not knowing what to expect from Chenin blanc when the style description is not clearly indicated on the label of a wine bottle. This study investigates the validity of this style classification by two separate sensory procedures. Firstly a sorting task was performed by wine industry experts to categorise 21 Chenin blanc wines based on their similarity. The second test involved descriptive sensory analysis (DSA) performed by a trained sensory panel to generate sensory profiles for each of the three styles. Results from the sorting indicated that there was no clear differentiation between FF and RRUW wine styles, however there was a clear differentiation between unwooded and wooded wines. DSA results indicated that FF wines correlated with "fresh fruit" and "tropical" flavours whereas descriptors generated for RRW wines included "rich fruit" and "wood" aromas. RRUW wines seemed to overlapped with the above mentioned styles and could not be placed into a separate group even with definite descriptors. The DSA results were in agreement with results from sorting which suggests that a continuum exists between these styles starting from fresh fruit resulting into rich or mature fruit. This is valuable information for the industry and should be applied to labelling methods that may lead to less consumer confusion.

4.1 INTRODUCTION

The flavour of wine can be described as a combination of taste and aroma attributes and is influenced by several steps in the winemaking process (Rapp, 1998; Polášková *et al.*, 2008). Sensory characteristics are very important for industries and are used as criteria to monitor the quality of products. Chenin blanc wines rely on fermentation derived aromas (Marais, 2005) and have been described to have fresh fruit and floral aromas, this includes fruit salad flavours such as apple, melon, apricot, guava and pineapple, as well as a firm, crisp and natural acidity in the final product. When the wine receives wood contact, the flavours get more complex with a richer mouth-feel. Other aromas that are introduced to the wine during bottle maturation may include aromas of nuts and honey to the wine (CBA. nd). Chenin blanc is an extremely versatile grape variety than can produce three different dry and semi-dry styles of wine: fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW). However, no sensory analyses have confirmed these styles of Chenin blanc. Furthermore, feedback from a leading South African retailer pointed out that the versatility is also perceived as a negative point, leaving consumers confused with not knowing what to expect from Chenin blanc when the style or description is not clearly indicated on the label (Brower, 2009). The question arises if there are indeed three distinctive wine styles of Chenin blanc and whether wine industry experts can identify these three styles.

Descriptive Analysis (DA) is a primary sensory method used in food sensory science that allows insight in the complete sensory profile of products including both qualitative and quantitative characteristics (Campo *et al*., 2010; Lawless and Heymann, 2010). Descriptive Sensory Analysis (DSA), a generic variant of DA, is the most popular of these techniques to generate sensory profiles for food (Stone *et al*., 1974; Chollet *et al*., 2011) and has been accepted and successfully used for the profiling of wine cultivars in combination with multivariate techniques (Sharma and Joshi, 2004; Chapman *et al*., 2004; Mirarefi *et al*., 2004). Examples of the use of DSA in wine sensory science includes a study by Aiken and Noble (1984), comparing aromas from wines that were aged in glass and oak. De la Presa-Owens and Noble (1997) used DSA to generate sensory profiles for Chardonnay wines that received different temperature treatments. Schlosser *et al*. (2004) found differences between the sensory attributes from different areas in Canada that produces Chardonnay. Cadot *et al*. (2010) investigated wine typicality related to a specific terroir with the use of DSA.

In the industry, judgements of wine experts are very important in wine analysis even though they did not receive extensive training in a profiling methodology such as DSA (Parr *et al*., 2002). Wine experts, such as winemakers, have too limited time and availability to take part in extensive DSA studies, and readily available results are fundamental. Thus, other methods, that are less time consuming, have been developed over the years. These methods include free choice profiling (Williams and Langron, 1984), projective mapping or napping (Risvik *et al*., 1994), flash profiling (Delarue and Sieffermann, 2004), and sorting tasks (Lelièvre *et al*., 2008) and do not demand training sessions.

A sorting task is a fast and simple method that can be applied to determine groups of products that are perceived as similar. Sorting is based on categorisation that is a natural cognitive process used on a regular basis in everyday life (Lelièvre *et al*., 2008). This method has been developed in the 1970's (Healy and Miller, 1970; Coxon, 1999). Since then, sorting has been applied to complex products including beer (Lelièvre *et al*., 2008; Chollet and Valentin, 2001) and various studies including wine. Gawel *et al*. (2001) characterised wines according to the mouth-feel properties and Piombino *et al*. (2004) used an inexperienced panel to sort 22 wines. The study proved that sorting, in combination with multidimentional scaling (MDS), is a technique that successfully allows for rapid and economical evaluation of a large number of samples. Other statistical techniques that can be used for analysing data of the sorting task include multiple correspondent analysis (MCA) and DISTATIS (Robert and Escoufier, 1976; Schiffman *et al*.,1981; Lawless *et al*., 1995; Abdi *et al*., 2007; Cadoret *et al*., 2009; Chollet *et al*., 2011).

Piombino *et al*. (2004) furthermore concluded in their study that, sorting is a successful qualitative and exploratory instrument as a preliminary step followed by traditional DA. Several studies have also proved that the results from sorting tasks are comparable with results from descriptive methods (Faye *et al*., 2004; 2006; Heymann, 1994; Saint-Eve *et al*., 2004; Tang and Heyman, 1999; Cartier *et al*., 2006; Perrin *et al*., 2007).

This study focus on the generation of sensory profiles for 42 South African Chenin blanc wines with DSA. Descriptors for the different styles of Chenin blanc are generated and their intensities are investigated for significant differences. Furthermore the validity of the three style classification is investigated with a sorting task performed by wine industry experts. Scientific exposition of the different styles may give wine producers the validity to give a correct style description to their wine that may lead to less confusion amongst Chenin blanc consumers.

4.2 MATERIALS AND METHODS

4.2.1 Sorting task performed by untrained wine experts

4.2.1.1 Wines

A sample set of 21 commercial wines were selected from a larger sample set (described in section 3.2.1) based on area, style and availability for the expert panel tasting. The 21 wines consisted of seven wines from each of the three styles: fresh and fruity (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW). The wines were selected to represent different styles of Chenin blanc available in different wine producing regions. FF wines normally do not receive wood contact or a maturation period and were mainly from the 2010 vintage that was readily available at the time of this study. RRW wines typically mature in oak for a period of time, therefore 2010 wines were not released into the market and mainly RRW wines from the 2009 vintage were included in this study. The distribution of style, vintage and wine producing area of the 21 wines used for the sorting task is given in Table 4.1.

Table 4.1 Distribution of samples used for expert tasting and sorting task.

Sample number	Fresh and Fruity (FF)		Sample number	Rich and Ripe Unwooded (RRUW)		Sample number	Rich and Ripe Wooded (RRW)	
	Area	Vintage		Area	Vintage		Area	Vintage
1	McGregor	2010	8	Worcester	2009	15	Malmesbury	2009
2	Tulbagh	2010	9	Paarl	2008	16	Riebeek Kasteel	2009
3	Villiersdorp	2010	10	Paarl	2010	17	Paarl	2009
4	Ashton	2010	11	Riebeek West	2010	18	Robertson	2009
5	Worcester	2010	12	Stellenbosch	2010	19	Greyton	2009
6	Calitzdorp	2010	13	Stellenbosch	2010	20	Stellenbosch	2009
7	Darling	2009	14	Stellenbosch	2009	21	Stellenbosch	2009

4.2.1.2 Sorting task: design and procedures

A panel of eight wine experts evaluated 21 Chenin blanc wines. The experts consisted out of Chenin blanc winemakers between the ages of 31 and 60. Five of the experts were male and three were female. Their experience in the wine industry ranged from 6 to 31 years. The expert panel did not receive any formal training with Chenin blanc, but used their knowledge and former experiences gained in the wine industry to evaluate the wines. Each panellist was seated at a separate table with a tray of 21 randomised wines and a questionnaire (Addendum A). Instructions provided to the panel included that each of the 21 wines should be evaluated on colour, aroma and palate attributes, i.e. similar to wine scoring in wine competitions. An overall score out of 20 was assigned to each wine for quality.

After evaluating the wines, the experts used a sorting technique (Lelièvre *et al*., 2008; Chollet *et al*., 2011) to group the wines according to their similarities. The panel formed different groups of wine that they perceived as similar without receiving information about the three wine styles (FF, RRUW, RRW). There was no restriction on the number of groups that could be formed. The main aroma and taste descriptors were used to describe each group of wines. Experts could complete this task on their own time on the day of evaluation.

4.2.1.3 Data analysis

Analysis of variance (ANOVA) was performed with Statistica 10 (Statsoft Inc., www.statsoft.com) to determine significant differences ($p \leq 0.05$) between the respective wines for each descriptor generated. Data of the sorting task were analysed using map representations including multidimensional scaling (MDS), multiple correspondent analysis (MCA) and DISTATIS (Abdi *et al*., 2007).

4.2.2 Descriptive Sensory Analysis by the trained panel

4.2.2.1 Wines

All of the wines that were used for the expert sorting (section 4.2.1.1) were selected for sensory profiling. Another 21 wines from a larger sample set (described in section 3.2.1) were added to perform an extensive in-depth sensory profiling of Chenin blanc. The wines were selected based on availability and a total of 42 wines were profiled for their sensory attributes. The styles, fresh and fruity wines (FF), rich and ripe unwooded (RRUW) and rich and ripe wooded (RRW) and the corresponding areas of the wines are indicated in Table 4.2.

Table 4.2 Wines selected for in-depth sensory profiling with descriptive sensory analysis (DSA).

Wines used for expert sorting task				Wines added to perform DSA			
Sample	Area	Vintage	Style	Sample	Area	Vintage	Style
1	McGregor	2010	FF	22	Robertson	2010	FF
2	Tulbagh	2010	FF	23	Breede River	2010	FF
3	Villiersdorp	2010	FF	24	Paarl	2010	FF
4	Ashton	2010	FF	25	Paarl	2010	FF
5	Worcester	2010	FF	26	Klawer	2010	FF
6	Calitzdorp	2010	FF	27	Cape Town	2010	FF
7	Darling	2009	FF	28	Bonnievale	2010	FF
8	Worcester	2009	RRUW	29	Wellington	2009	FF
9	Paarl	2008	RRUW	30	Robertson	2008	FF
10	Paarl	2010	RRUW	31	Stellenbosch	2009	FF
11	Riebeek West	2010	RRUW	32	Stellenbosch	2009	FF
12	Stellenbosch	2010	RRUW	33	Breede River	2009	FF
13	Stellenbosch	2010	RRUW	34	Paarl	2008	RRUW
14	Stellenbosch	2009	RRUW	35	Stellenbosch	2007	RRW
15	Malmesbury	2009	RRW	36	Stellenbosch	2008	RRW
16	Riebeek Kasteel	2009	RRW	37	Stellenbosch	2008	RRW
17	Paarl	2009	RRW	38	Paarl	2008	RRW
18	Robertson	2009	RRW	39	Tulbagh	2007	RRW
19	Greyton	2009	RRW	40	Swartland	2008	RRW
20	Stellenbosch	2009	RRW	41	Stellenbosch	2009	RRW
21	Stellenbosch	2009	RRW	42	Stellenbosch	2009	RRW

4.2.2.2 Descriptive Sensory Analysis: designs and procedures

Comprehensive sensory analysis was conducted on the 42 selected Chenin blanc wines (Table 4.2). Ten trained panellists used conventional descriptive sensory analysis (DSA) to analyse attributes of Chenin blanc (Lawless and Heymann, 2010). All the panellists had previous experience of wine analysis but were not regarded as wine experts. Twelve sessions, each consisting out of 2.5 hours, were used to train the panel, mainly to assist them in recognising the attributes of the 42 wines. For the first training session a list of terms, generated by the expert panel (section 4.2.2) and some descriptors from the Chenin blanc aroma wheel (CBA, nd), was introduced to the panel as proposed attributes present in the wine, together with corresponding reference standards (Table 4.3). Flavour samples for reference standards were added to a neutral wine (Drostdy Hof Extra Light dry white, South Africa) according to the specified concentrations. The list of reference standards together with the supplier and concentrations are listed in Table 4.3.

Two control wine samples were included during following training sessions namely a "fresh and fruity" wine and a "rich and ripe wooded" wine. The panel agreed on attributes and the corresponding intensities in the control wines and use these wines throughout the training and testing phase to calibrate themselves. After each training session, the attributes and reference standards were modified and updated until consensus were reached. After the training period, the trained assessors analysed the wines in booths fitted with Compusense® five (Compusense, Guelph, Canada) for capturing data. All analyses were conducted in standard artificial daylight and with a controlled temperature of 20°C ± 1°C. Samples (30 mL) were served in standard ISO wine tasting glasses covered with plastic lids to prevent aroma loss before analysis. The wines were evaluated over a period of five days. Three replications of eight to ten samples were analysed per day. The samples were labelled with three-digit codes and presented in a randomised design to balance carry-over effect. Each attribute was scaled on a 100 point unstructured line scale with the terms "low intensity" on the left and "high intensity". All the wines were scored in relation to the controls.

4.2.2.3 Data analysis

DSA was performed during three replicate tests while using a randomised complete block design. The data was captured with *Compusense five®, (*Compusense, Guelph, Canada). *PanelCheck®* software (Version 1.3.1, Nofima Mat, Norway) was used to test for panel reliability. Analysis of variance (ANOVA) was performed using STATISTICA 10® (Statsoft Inc., www.statsoft.com) to determine significant differences ($p \leq 0.05$) between wines for each sensory descriptor.

The Unscrambler® software (version 6.11, Camo ASA, Trondheim, Norway) was used to perform principal component analysis (PCA) to identify relationships between attributes in the different wine styles, as well as investigate sample patterns.

Table 4.3 Information regarding reference standards used to train the panel for flavours in Chenin blanc.

Main tier attributes	Reference Standards	Formulation	Supplier	Reference number	Dosage in 200 mL of natural wine
Citrus	**Lemon**	Fresh lemon in distilled water			24g
	Orange (nr 1)	Orange Sweet reference standard	IFF	10825353	100µL
	Orange (nr 2)	Fresh orange slice, remove peel			
	Grapefruit fresh	Fresh grapefruit slice, remove peel			24g
	Citrus	Grapefruit reference standard	Sensient	C1859	30µL
Stone fruit	**Apricot**	Apricot Flavouring reference standard	Cargill	F-10922	20µL
	Peach	Peach reference standard	Sensient	F9371	33µL
Tropical fruits	**Melon nr 1 (Winter melon)**	Melon reference standard	Sensient	1007873	100µL
	Melon nr 2	Fresh melon, slice			
	Pineapple	Fresh pineapple, slice			
	Pineapple/Guava	Guava reference standard	Firminich	Sample box	33µL
	Guava	Mango reference standard	Firminich	Sample box	30µL
	Guava	Fresh, slice with peel			
	Litchi	Litchi reference standard	Firminich	Sample box	25µL
	Passion fruit (nr 1)	Passion fruit D1556 reference standard	IFF	108352	100µL
	Mango	Mango reference standard	Sensient	1041975	50µL
Sweet associated	**Caramel**	Butterscotch reference standard	Sensient	1043727	33µL
	Marmalade Seville	In a Petri dish	All Gold		
	Marmalade Seville	Marmalade in wine			30mL
	Stewed fruit (Compote)	Dried fruit mix with warm water			
	Honey	Natural honey in wine			30mL
Floral	**Honey Blossom**	Honey reference standard.	Firminich	Sample box	50µL
	Orange Blossom	Orange blossom			
Spicy	**Spicy (sweet spice)**	Spicy	Robertson spice	Mixed spice	3mL
	Spicy (savoury/wood)	Spicy	Robertson spice	All spice	3mL
Vegetative	**Tea**	Tea reference standard	Cargill	1000539197	50µL
	Green pepper	Fresh green pepper			
	Asparagus	Fresh asparagus			

4.3 RESULTS AND DISCUSSION

4.3.1 Sorting results

In this study, the data from the 21 wines that has been sorted by the wine industry experts were analysed via MDS as well as DISTATIS. The results for these two techniques were similar and only results from DISTATIS are shown in Figure 4.1. The first two principal components explained only 38.8% of the variance in the data. Lawless and Heymann (2010) mentioned that the variance explained for and untrained panel are expected to be between 15-24% for the reason that the terms that are used, are not standardised. RRW wines are located on the right side of PC1. These wines are arranged near each other in the plot indicating that the RRW wines were often group together by the experts. FF and RRUW wines associated on the left side of the graph. Unlike RRW, these two wine styles did not form separate groups showing that overlapping between the groups occurred more often. Lelièvre *et al.* (2009) mentions that wine experts with prolonged experience to similar wines have strong memory knowledge. The results indicate that there were no clear differentiations between FF and RRUW wines as perceived by wine experts, indicating that they do not have a strong memory of these styles and perceived FF and RRUW as similar.

Discrimination between RRW and the other two styles mainly occurs along the first axis indicating a trend of results that the experts clearly identified RRW wines. This suggests that this wine style have unique flavour features which are absent in the FF and RRUW wines. The latter two styles seem to have some flavour characteristics in common.

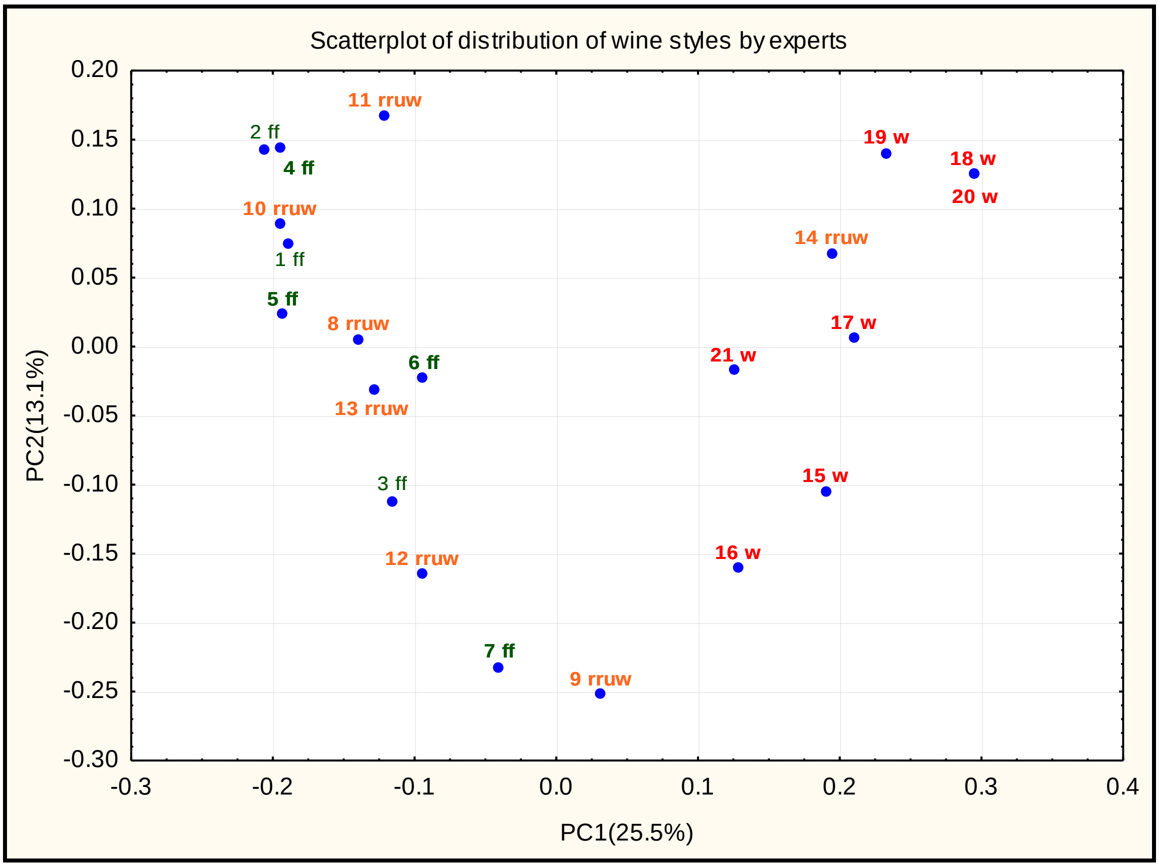

Figure 4.1 Scatterplot indicating distribution of wine styles (FF, RRUW, RRW) as sorted by wine experts.

Significant different aroma compounds, generated by the experts to describe their groups of wines, were identified by ANOVA and were selected for further analysis. Cluster analysis (CA) was used to plot these aroma descriptors represented in Figure 4.2a. The first two dimensions of this graph explained 83.06% of the variance in the data. The aroma descriptors associated with the RRW wines in dimension one were "wood", "sweet associated", "ripe fruit" and "complex". Descriptors that were associated with FF and RRUW wines were "citrus", "fruity", "fresh" and "tropical".

In Figure 4.2b the aroma attributes are shown that experts used for describing the individual wines apart from the different groups of wines. The first two components explained 49.45% of the variance. The descriptors associated with RRW individual wines included "wood", "sweet", "honey", "complex", "spicy", "ripe" and "intense". Individual wines of FF and RRUW were mostly associated with "fruity", "tropical", "green", "citrus", "floral" and "neutral" descriptors. The palate attributes were also investigated for individual wines (data not shown). Attributes associated with RRW included "sweet", "wood", "complex", "balanced", "ripe", "rich", and "aged". Wines from FF and RRUW were associated with "tropical", "fruity", "crisp", "fresh", "medium", "citrus" and "neutral" palate attributes.

It is clear from Figure 4.2a and b that individual descriptors used for individual wines give rise to more descriptors to describe the different wine styles. Coarser descriptors were identified if attributes were assigned to a wine group rather than individual wines. However, more variance is explained by assigning descriptors to groups of wines (Figure 4.2a) rather than individual wines (Figure 4.2b).

It is evident from Figure 4.1, Figure 4.2a and Figure 4.2b that there is a definite differentiation between wooded and unwooded wines. RRW wines were grouped on the right side in each data plot, whereas FF and RRUW wines associated on the left side with no clear differentiation between these two styles. This indicates that wine experts could not differentiate between FF and RRUW Chenin blanc wine styles, however there was a clear differentiation between unwooded and wooded wines. This may also indicate that no significant differences between FF and RRUW exist, and that these three styles form a continuum from fresh to rich mature fruit aromas. Similar sorting results were also found by Ballester *et al.* (2009) who asked wine experts to sort red, white and rosé wines according to their aroma. The wines were served in dark tasting glasses and results indicated that experts could correctly classify between red and white wine aromas, but the rosé wines were not correctly classified.

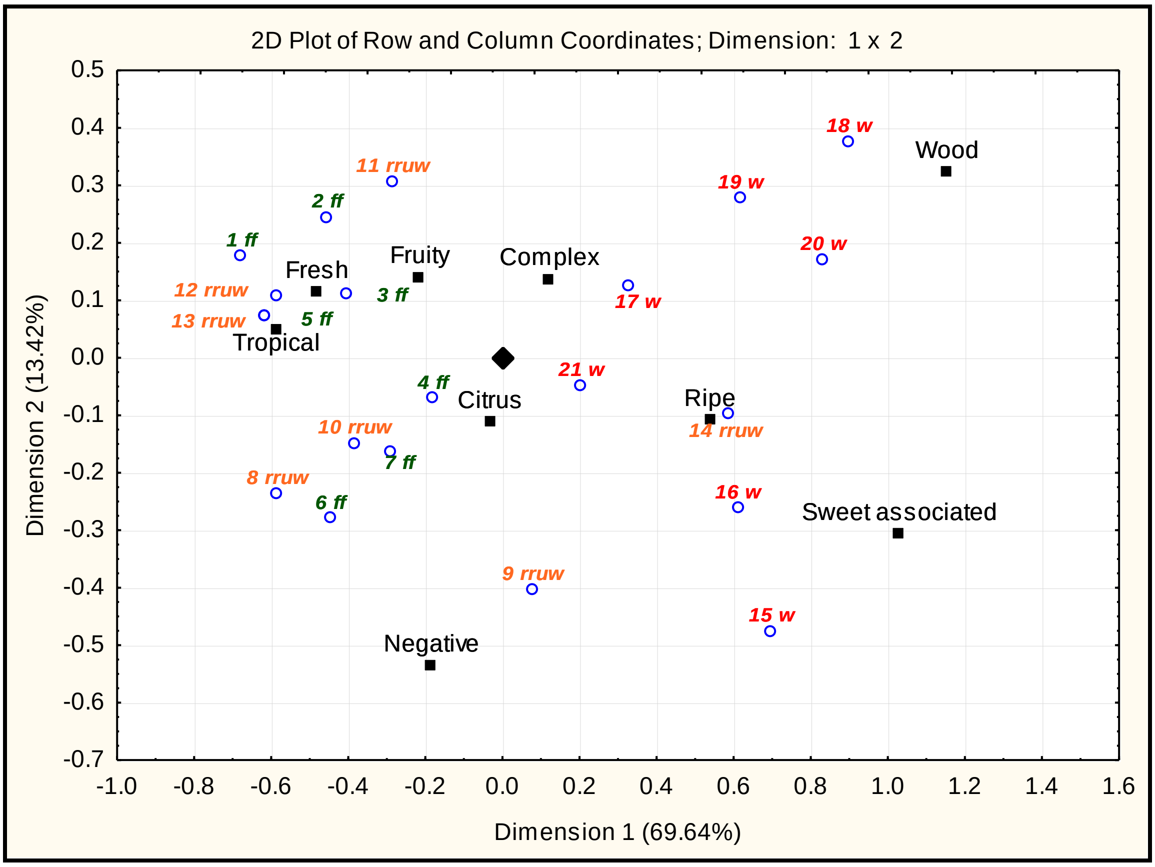

Figure 4.2a Correspondence analysis bi-plot of main descriptors used for wine style groups.

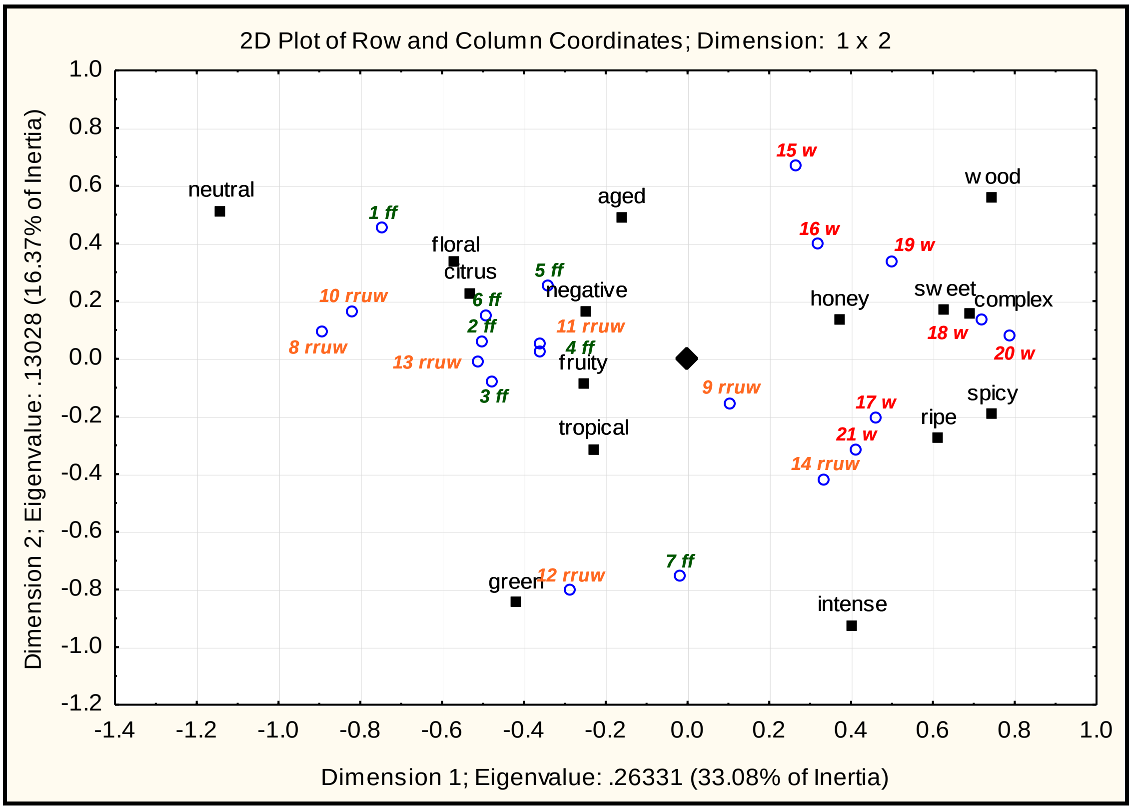

Figure 4.2b Correspondence analysis bi-plot of main descriptors used for individual wines.

4.3.2 Descriptive Sensory Analysis (DSA) results

During training panellists generated a list of 39 attributes that included aroma and palate attributes that was used to evaluate the wines during testing (Table 4.4). Attributes that were generated included the main aroma attributes tropical, citrus, stone fruit, rich fruit, floral, sweet associated, vegetative, woody and spicy. These main attributes were broken down into more specific descriptors. Palate descriptors consisted only out of the main descriptors. The ranges, mean intensity and standard deviation for each of the three styles were determined from the score per attribute. Significant differences are calculated at the 5% level of significance ($p \leq 0.05$). Letters (a, b and c) next to the mean concentration indicate the significant differences between these mean intensity concentrations per compound for each style. The the superscript letter "a" indicates the significant highest mean concentration. Concentrations with different letters indicate a statistical difference whereas the same letter indicates that the values are not significantly different from each other.

Table 4.4 indicates that FF wines have a higher intensity of "tropical", "fresh fruity", "citrus", "floral" and "stone fruit" flavours. These wines also tend to have more acidity. The RRW wines were associated with "woody", "spicy", "rich fruit" and "sweet associated" flavours. The PCA loadings plot (Figure 4.4a) displays die main sensory attributes that was used to evaluate the wines. The attributes "citrus", "tropical" and "fresh fruity" flavour are descriptors that correlate positively towards each other on the right side of PC 1. On the left side of PC 1 the "wood" and "rich fruit" flavours were highly correlated with each other. The first two principal components (PC's) explain 75% of the total variance in the data. Lawless and Heymann (2010) mentioned that a well-trained panel could easily have an explained variance ranging from about 50% to 70% on the first dimension. In our study the amount of variance explained by the first PC (58%) indicated the panel was well trained.

The PCA score plot (Figure 4.4b) displays the wine styles in terms of the aroma and palate attribute intensities and the wines in relation to one another. RRUW (2) wines overlapped between FF (1) and RRW (3) styles with some wines consisting out of more fresh and fruity characteristics and some more of rich and ripe attributes. Lund *et al.* (2009) also used DSA to profile the distinctive sensory properties of New Zealand (NZ) Sauvignon blanc in relation to other international wines. The study found that Marlborough wines from NZ had some sensory characteristics with higher intensity levels than other wines, however, these wines overlapped with wines from Wairarapa (NZ), which indicated similarities among the individual wines.

The same conclusion was made when discussing the results of the sorting technique with wine experts (section 4.3.1), i.e. that instead of three distinctly defined styles of Chenin blanc, there is rather a continuum from fresh fruity evolving into rich fruit. Perrin *et* al. (2007) also found that the results from sorting by wine experts were comparable with results from the descriptive methods by using a trained panel.

Table 4.4 Ranges, mean and standard deviation of aroma and palate attributes determined by a trained panel on wines classified as FF, RRUW and RRW.

	Fresh and Fruity (FF)				Rich and Ripe unwooded (RRUW)				Rich and Ripe wooded (RRW)			
Aroma attributes	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]
TROPICAL	10.48	47.87	30.80^{a}	9.18	1.33	41.56	19.34^{b}	15.50	0.00	20.41	5.83^{c}	7.43
Guava	1.28	10.22	5.58^{a}	2.81	0.00	8.89	3.57^{a}	3.06	0.00	3.39	1.12^{b}	1.19
Green Guava	0.00	11.59	1.98^{a}	3.25	0.00	10.26	2.16^{a}	3.43	0.00	1.11	0.25^{b}	0.40
Pineapple	5.13	24.54	15.67^{a}	5.37	0.00	21.00	9.06^{b}	7.98	0.00	13.24	3.21^{c}	4.43
Litchi	0.00	3.30	0.85^{a}	0.93	0.00	4.09	0.63^{ab}	1.42	0.00	1.09	0.15^{b}	0.33
CITRUS	1.11	12.26	6.24^{a}	3.11	0.37	8.43	3.40^{b}	2.62	0.00	6.52	2.21^{b}	1.78
Orange (fresh/peel)	0.50	5.57	2.96^{a}	1.53	0.39	4.50	1.46^{b}	1.32	0.00	2.93	1.01^{b}	0.91
Grapefruit	0.00	3.85	1.54^{a}	1.05	0.00	2.11	0.82^{ab}	0.78	0.00	3.24	0.65^{b}	0.86
STONE FRUIT	0.00	2.56	0.96^{a}	0.84	0.00	4.28	0.86^{ab}	1.53	0.00	2.48	0.32^{b}	0.66
Peach/Apricot	0.00	2.02	0.74^{a}	0.63	0.00	2.91	0.62^{ab}	1.06	0.00	2.39	0.28^{b}	0.64
RICH FRUIT	2.96	22.83	10.99^{c}	5.53	8.02	32.91	20.44^{b}	9.82	16.70	48.30	35.74^{a}	9.53
Marmalade	0.57	9.74	3.92^{b}	2.73	1.67	10.52	5.60^{b}	3.04	3.22	21.09	11.10^{a}	5.14
Compote	0.48	6.69	2.31^{c}	1.67	0.48	13.69	5.50^{b}	4.24	4.39	17.06	10.15^{a}	3.87
Raisin	0.37	7.85	3.05^{b}	2.06	0.52	9.81	5.43^{b}	3.45	5.61	18.63	10.08^{a}	3.79
Prune	0.00	2.09	0.63^{b}	0.56	0.00	2.78	0.97^{ab}	0.89	0.00	6.41	2.10	1.94
FLORAL	1.39	15.09	7.35^{a}	3.65	0.00	14.04	4.62^{ab}	4.75	0.00	5.87	2.66^{b}	2.17
Honey blossom	0.00	9.69	3.44^{a}	2.35	0.00	5.37	1.41^{b}	1.74	0.00	4.50	1.70^{b}	1.55
Orange blossom	0.00	3.13	1.20^{a}	0.89	0.00	4.59	1.21^{a}	1.57	0.00	2.22	0.37^{b}	0.73
SWEET ASSOCIATED	4.72	18.98	10.49^{b}	4.60	5.81	22.17	12.56^{b}	4.69	12.48	38.63	23.11^{a}	7.05
Honey	2.09	9.57	4.30^{b}	1.94	1.65	13.07	6.06^{b}	3.41	5.22	28.04	13.48^{a}	6.65
Vanilla	0.00	1.33	0.16^{a}	0.31	0.00	0.19	0.03^{a}	0.07	0.00	0.63	0.19^{a}	0.21
VEGETATIVE/GREEN	2.59	31.07	9.24^{a}	7.23	5.28	18.35	9.75^{a}	4.26	0.00	11.83	4.86^{b}	3.81
Asparagus	0.00	13.94	2.02^{a}	3.26	0.00	3.31	1.04^{a}	1.16	0.00	3.74	1.11^{a}	1.05
Green Pepper	0.00	9.57	1.82^{ab}	2.61	0.00	9.69	2.96^{a}	3.42	0.00	4.76	0.79^{b}	1.39
WOODY	0.00	18.26	2.99^{b}	4.60	0.00	23.28	8.60^{b}	9.28	3.83	54.02	23.19^{a}	16.10
Planky	0.00	3.35	0.53^{a}	0.84	0.00	1.80	0.69^{a}	0.71	0.00	3.83	1.08^{a}	1.26
High roast	0.00	8.63	1.03^{b}	2.05	0.00	11.04	3.38^{b}	4.55	0.37	30.85	12.17^{a}	10.00

Table 4.4 continued Ranges, mean and standard deviation of aroma and palate attributes determined by a trained panel on wines classified as FF, RRUW and RRW.

	Fresh and Fruity (FF)				Rich and Ripe unwooded (RRUW)				Rich and Ripe wooded (RRW)			
Aroma attributes	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]	minimum	maximum	mean	±SD[1]
Coffee	0.00	1.48	0.13[b]	0.35	0.00	1.67	0.49[ab]	0.73	0.00	6.41	1.22[a]	1.99
SPICY	0.00	4.80	1.24[b]	1.37	0.02	7.65	3.08[b]	2.91	1.70	22.26	7.42[a]	5.80
BUTTER	0.00	1.37	0.51[b]	0.51	0.00	3.85	0.94[ab]	1.25	0.00	9.17	2.76[a]	3.28
Palate attributes												
FRESH FRUITY_F	13.07	42.56	27.32[a]	8.88	0.00	46.50	18.05[b]	16.17	0.00	19.52	5.24[c]	6.20
RIPE/COOKED FRUIT_F	1.17	22.46	11.34[b]	7.38	4.07	27.94	17.19[b]	9.28	16.70	49.20	34.07[a]	9.36
VEGETATIVE_ F	0.81	17.78	6.11[a]	4.83	3.13	15.89	7.50[a]	4.36	0.00	8.67	2.89[b]	2.47
WOOD_F	0.00	12.31	2.30[b]	3.40	0.00	19.65	7.35[b]	6.67	4.24	58.39	23.76[a]	16.41
SWEET_T	22.31	29.07	26.12[b]	1.38	22.44	27.28	25.17[b]	1.79	24.04	32.43	27.72[a]	2.74
ACIDITY_T	22.87	34.94	28.37[a]	2.97	24.80	30.91	27.71[ab]	2.07	21.09	31.33	26.91[b]	3.15
BITTER_T	0.00	1.57	0.72[a]	0.53	0.19	2.35	0.99[a]	0.78	0.13	1.63	0.95[a]	0.46
ASTRINGENCY_M	10.65	15.94	13.18[b]	1.22	12.44	15.57	13.94[b]	1.08	12.98	16.72	14.80[a]	1.04

[1]Standard deviation F = Flavour; T = Taste; M = Mouth-feel.

Significant differences are indicated in rows. Wine attributes that differ significantly ($p \leq 0.05$) between different styles (FF, RRUW, RRW) are indicated with superscript letters (a, b and c) next to the mean concentration. The superscript letter, “a” indicates the highest mean concentration. Concentrations with different letters indicate a statistical difference whereas the same letter indicates that the values are not significantly different from each other.

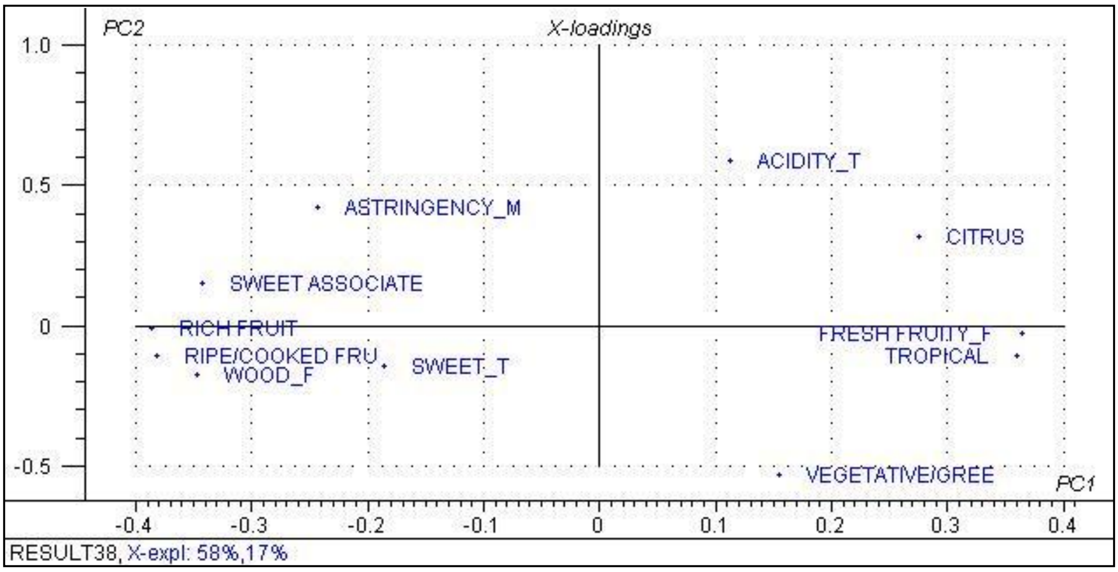

Figure 4.4a PCA loadings plot of main sensory attributes (aroma and taste descriptors).
F = Flavour; T = Taste; M = Mouth-feel descriptors perceived by tasting the wines.
RIPE/COOKED FRU = RIPE/COOKED FRUIT_F; VEGETATIVE/GREE= VEGETATIVE/GREEN.

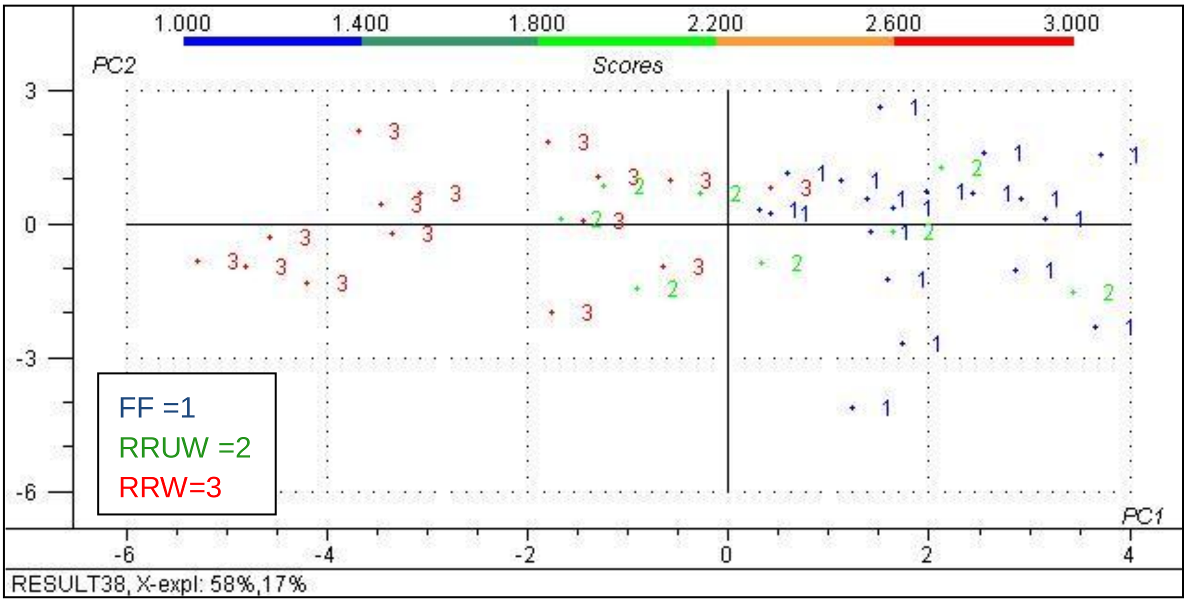

Figure 4.4b PCA scores plot of wines in relation to the sensory attributes.

4.4 Conclusions

Chenin blanc is a versatile variety that responds to the different wine making and oenological techniques by producing different styles of wine, including the dry styles 'fresh and fruity', 'rich and ripe unwooded' and 'rich and ripe wooded'. However, no sensory analysis has confirmed these styles. Results from the sorting done by wine experts indicated that there was no clear differentiation between FF and RRUW Chenin blanc wine styles, however there was a clear differentiation between unwooded and wooded wines. This may also indicate that no significant differences between FF and RRUW exists, and that these three styles forms a continuum from fresh resulting in rich mature fruit aromas

Descriptive sensory analysis was used to development sensory profiles for each of these styles. FF wines correlated with "fresh fruit" and "tropical" flavours. Descriptors generated for RRW wines included "rich fruit" and "wood" flavour. RRUW wines seemed to overlapped with the above mentioned styles and could not be placed into a separate group with definite descriptors. The sensory maps confirms the results from sorting which suggests that a continuum exists between these styles starting from fresh fruit resulting into rich or mature fruit. This is valuable information for the industry and should be applied to labelling methods that may lead to less consumer confusion.

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Chapter 5

General conclusions

General Conclusions

5.1 Conclusions

Chenin blanc, being the most cultivated grape variety in South Africa (SA), is, strangely, also the least researched variety in SA. The reasons for this can possibly be ascribed to this wine category's relatively recent rise in quality and international recognition thereof. In addition to addressing the scientific questions of chemical and sensory profiling of the wines, the industry problem that deals with the need to re-evaluate the classification of dry and semi-dry Chenin blanc wine styles is both challenging and urgent.

Findings of this study indicated that volatile compounds showed a statistically significant, however, subtle differentiation between FF and RRW wine styles, but RRUW wine styles overlapped with these wine styles. In terms of the volatile compounds, a continuum is found, rather than three separate styles.

Sensory analysis conducted with two separate techniques also confirmed the result of the evaluated underlying chemistry. Wine experts could clearly differentiate between FF and RRW, whereas they could not clearly identify RRUW wines. This was also the case for the conclusions reached by the trained sensory panel. The findings of this research project were communicated at several conferences and workshops to the industry during the course of the study and form a basis from which a new labelling system for Chenin blanc can be designed. Based on retail feedback, there is clearly a need for a labelling system in Chenin blanc, that succeeds in educating and informing wine consumers about the fresh fruit to rich fruit continuum that are present in Chenin blanc wines, and that this feature is in fact an intricate characteristics of this wine variety. It may lead to less consumer confusion in the future if consumers can familiarise themselves with the types of diversity in this cultivar. Additional future studies can also include correlation studies between chemical data and sensory data, particularly if data pertaining to the volatile thiols and wood-derived compounds for instance, are included. This could lead to the possible prediction of wine style, based on chemical markers uniquely present in each style.

The vintages of two consecutive years per style were investigated. The aroma compounds showed no overall significant differences between FF (2009 an 2010) and RRW (2009 and 2010) respectively. This suggests that for each style, the overall volatile profile may show some consistency, indicating the existence of a typical volatile profile, and can be used in comparison studies with other volatiles of different cultivars.

The volatile composition was investigated to determine if significant differences amongst different areas exists. The chemical analysis done in this study was the first round of a complex and multi-facetted task and the results can be considered as the first steps towards the establishment of SA Chenin blanc wine profiles. This is particularly relevant if the importance of non-volatile compounds such as phenolic compounds, organic acids and other, that affect taste and mouth-feel, is also taken into consideration. However, it would seem as if the future classification of Chenin blanc should be on the basis of sensory or stylistic characters, rather than geographic origin.

Finally, it has been stated in this thesis that the effects of different vinification practices can largely influence the stylistic characteristics of Chenin blanc wine. In the SA context, the effect of some practices such a limited skin contact prior to fermentation or spontaneous fermentations should be investigated.

Addendum A

Questionnaire used for evaluation of individual wines

Addendum A

Name :________________   Panelist #_______

Gender: M / F   **Age**: <25, 26-30, 31-40, 41-50, 51-60, >60

How many years in Wine Industry? ____ **Occupation**:__________________

Dear panelist,

Please follow the instructions as follows:

NOTE: please use the water and biscuits to cleanse your pallet between wines.

Sorting task:

1. Evaluate all 21 wines from left to right, one at a time, on **aroma, taste and colour**. Please write all the descriptors you associate with the wine in the space provided next to the corresponding number.

2. Evaluate each wine again in any order and **sort the wines into groups in front of you according to style differences. Group wines together that you perceive as similar to one another**.
   NOTE: you may place as many wines into a group as you want if you feel that they are all similar to each other. You may create as many groups as you want.

3. After sorting the 21 wines into groups you should **indicate** on **which wines are grouped together** by writing the number of the wines (1 – 21) in a group within one of the blocks as provided in the table.

4. Please evaluate the wines that you grouped together and write down the **descriptors** you perceive to be dominating in that group.

5. Please indicate **3 wines** in a group that are most representative / typical of that group.

Name___________________________ Panelist# __________

Sample	Description: Aroma, Taste and Colour	Group:	Score out of 20
1	Aroma: Taste: Colour:		
2	Aroma: Taste: Colour:		
3	Aroma: Taste: Colour:		
4	Aroma: Taste: Colour:		
5	Aroma: Taste: Colour:		

6	Aroma: Taste: Colour:		
7	Aroma: Taste: Colour:		
8	Aroma: Taste: Colour:		
9	Aroma: Taste: Colour:		
10	Aroma: Taste: Colour:		
11	Aroma: Taste: Colour:		

12	Aroma: Taste: Colour:		
13	Aroma: Taste: Colour:		
14	Aroma: Taste: Colour:		
15	Aroma: Taste: Colour:		
16	Aroma: Taste: Colour:		
17	Aroma: Taste: Colour:		

18	Aroma: Taste: Colour:		
19	Aroma: Taste: Colour:		
20	Aroma: Taste: Colour:		
21	Aroma: Taste: Colour:		

Table 2 Please indicate wines grouped together by writing all the numbers of a group below each other, followed by a description of no more than 5 words for the group.

	Group ___	Group ___	Group ___	Group ___	Group ___	Group ___	Group ___
Wine numbers grouped together							
Group descriptors							